DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

FEBRUARY 1961

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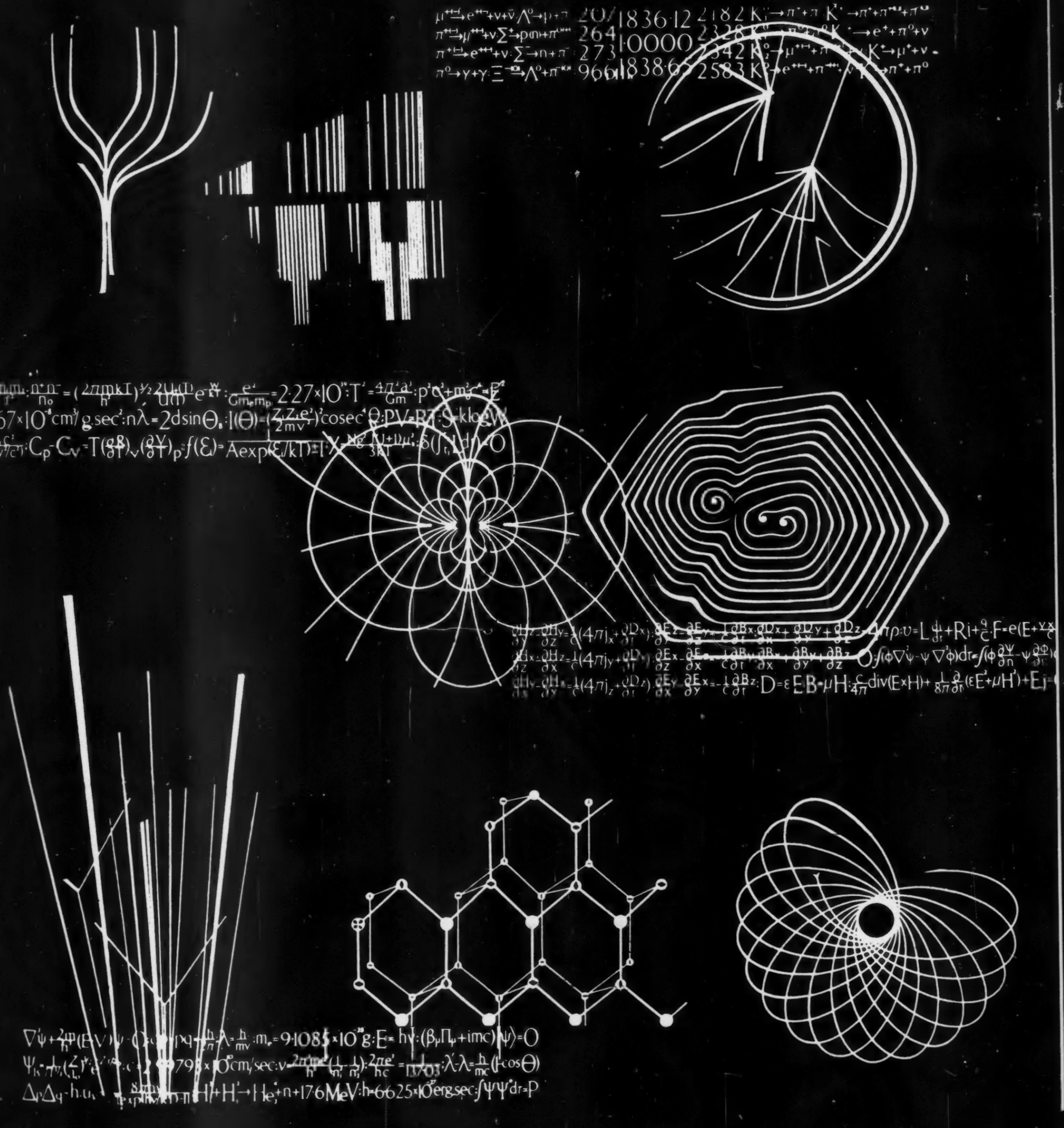

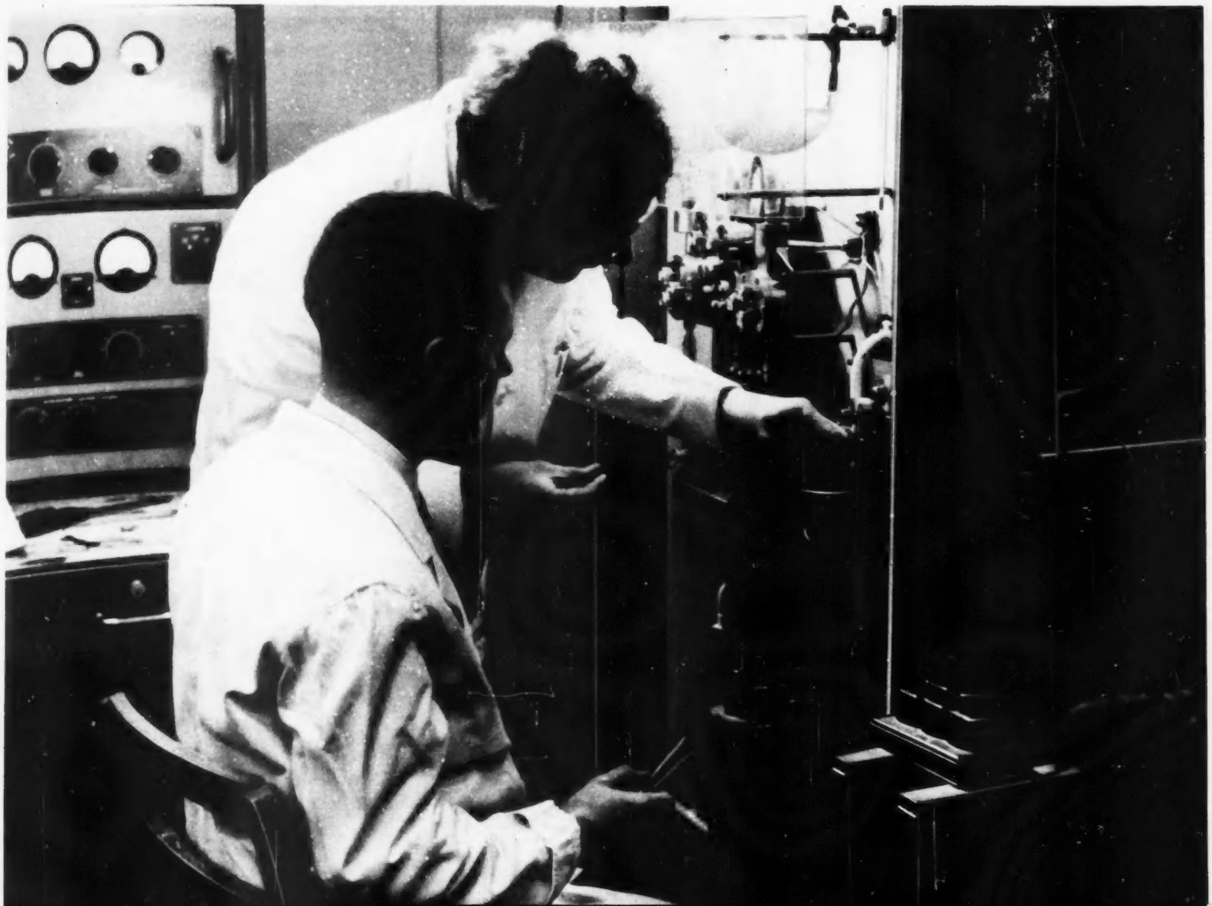

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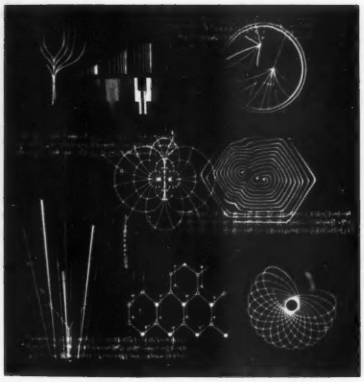

Figures from frieze over entrance to new Physics building at Imperial College, London; see p. 45.

DISCOVERY

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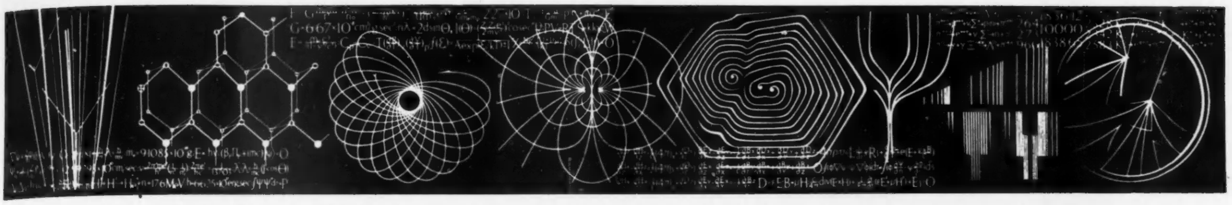


A MORE WIDESPREAD UNDERSTANDING OF SCIENCE THROUGH ART

The present body of knowledge that comes under the heading of Physics is symbolised in a striking manner in this sculptured frieze over the main entrance of the new Physics Building of Imperial College, London. Seven figures illustrate significant developments in various fields and the four blocks of equations overlapping them, in a manner reminiscent of the hieroglyphics in early Assyrian bas-reliefs, describe major physical theories.

Carved in black Irish limestone, the frieze is the joint idea of sculptor John Skeaping and P. M. S. Blackett, Professor of Physics at Imperial College.

Starting from the left, the first figure represents the first observation of nuclear transformations in the cloud chamber. The next figure illustrates the structure of crystals by showing the arrangement of carbon atoms in a diamond. The third, symbolising the precession of an elliptical orbit, represents the motion of satellites, be they planets, *Sputniks*, or electrons. The central figure is the ubiquitous dipole field. Next is a figure showing the dislocations and spiral lines of growth of a crystal surface—phenomena of importance in the theory of solids. The composite that makes up the sixth figure shows first a typical converging series of spectral lines and then the splitting of spectral lines by magnetic and electric fields. The last design illustrates the discovery of "fundamental" particles in bubble chambers and photographic emulsions with high-energy accelerators.

The equations in the left-hand block describe quantum theory and give various fundamental quantities in atomic physics. The second set covers such topics as gravitation, thermodynamics, and relativity. The equations in the third block are the principal ones of electromagnetism and include those of Maxwell. The final set gives the masses of "fundamental" particles and transformation equations.

This frieze symbolises something more than the broad scope of physics. It is a sign of the growing desire on the part of scientists to make basic knowledge and the scientific method more widely known. As the non-scientific segment of the community usually makes a wide detour around what appear to be impossibly complex concepts, it may be possible to approach them through a medium they accept more readily—Art.

Relatively few people claim to understand what Picasso has tried to say in his paintings; yet approximately 500,000 people queued up to see his work during a 9-week exhibition in London recently. How many would have gone to see an exhibition of, say, molecular models showing how life may have originated, or a display of photographs of the historic particle tracks which revealed the existence of what are now considered fundamental particles? This disparity may be explained away by saying the public just is not interested in science and never will be, but such an explanation may just be a cover for a lack of interest or imagination on the part of the scientists themselves.

If an approach can be made through art, ways must be found of getting the artists interested in this kind of subject-matter. The most direct means is by sponsoring or commissioning works. Why not? Many of the great works of art have been created under the aegis of church and throne; the popularisation of science through art calls for similar support from industry and university. The way is being pointed out by such companies as Mullard Ltd, which in 1959 commissioned a series of abstract paintings by Roy Nockolds on eight technical subjects—radar, television, communications, transistors, guided weapons, nuclear fission, X-rays, and computers. Although these paintings were primarily intended for advertising purposes, there has been a sizeable demand for prints from schools, art colleges, technical institutions, industry, and the general public. Mullard is now holding a competition among ten British sculptors for a design which will symbolise the work of an electronics laboratory, the results of which are expected to be announced very soon.

Scientists are usually roundly criticised whenever their discoveries are used for destructive ends or produce social dislocations. In the eyes of the general public, the scientists (engineers are usually included in this expression) are the ones who are basically responsible for the nuclear bombs, the even more destructive weapons of chemical and biological warfare, and the proliferating array of missiles, anti-missile missiles, and anti-missile-missile decoys. The scientists are the ones who are creating automatic machines and, indeed, automatic factories that have begun to put men out of work. The scientists are the ones who are developing electronic brains that can not only do but can also learn, think, and create. And now they are experimenting with genes and chromosomes and the basic molecules of living matter.

The scientists can no longer afford the luxury of quiet isolation. They and the work they do must be better understood by the public if they are to obtain the funds and support they need and if they are to avoid the criticism and hostility that are bound to result from the use or abuse of the great discoveries that are yet to come. There are many ways of approaching the public; art has much to offer.

R. K. M.

THE PROGRESS OF SCIENCE

DISCOVERY IN ANTARCTIC PUZZLES SCIENTISTS

The discovery of the partially decomposed remains of fish and invertebrates on the surface of the Ross Ice Shelf in the Antarctic about a mile and a half from the waters of McMurdo Sound has U.S. scientists puzzled as to how they got there. Bone samples have been sent to New Zealand for carbon-14 dating. Should the fish prove to be very old, it will give strong support to the theory that they were trapped in the ice by the freezing of the ice shelf to the sea floor and were subsequently brought to the top by the progressive melting of the upper surface and the formation of new ice on the bottom surface of the shelf. Well over fifty of the remains were found by a research party from the University of Michigan. The leader of the group, Dr C. W. M. Swithinbank, speculates that it might have taken anywhere from 100 to 2000 years for the fish to reach the surface, depending on the thickness of the ice and the rate of surface melting. If the fish are found to have died recently, some other explanation must be found for their presence on the ice surface so far from the open sea. Although Swithinbank, a glaciologist who has spent many seasons in the Antarctic, believes that the main body of the Ross Ice Shelf is nourished principally by the accumulation of snow on its upper surface, he agrees that the discovery may show replenishment has been taking place from the bottom—an unusual occurrence for a permanent floating ice sheet of considerable area and thickness, the only known parallel being the small ice shelf off the north coast of Ellesmere Island in the Arctic. Support for this explanation is added by an observation made in this region during the recent winter by the Russian glaciologist Sveneld Evteev who was working at the U.S. station on an exchange basis. Evteev found sea ice as well as fresh water ice at the site.

Although most of the Ross Ice Shelf is 600–2500 ft. thick, the area in which the fish were found is believed to be something over 100 ft. thick; the surface at this point is at least ten to fifteen feet above sea level.

The largest fish found measured sixty-five inches in length although some of the detached heads seemed to have come from still larger ones. They appeared to be members of at least two genera of *nototheniidae*, the most common group of Antarctic fishes, although none this large has ever been found in the waters of McMurdo Sound and the Ross Sea.

The numerous deep-water invertebrates found included pelecypods (bivalves or clams), gastropods (univalves or snails), brachiopods (lamp shells), siliceous sponges, and anthozoan corals. Some of them were extremely fragile and several of the glass sponges were still attached to rocks that came up with them from the sea floor.

The Ross Ice Shelf is the largest unbroken mass of floating ice in the world. It has an area of 196,000 sq. miles —about that of Spain.

A QUANTUM JUMP IN TELEPHONE VERSATILITY

A new telephone system which is highly versatile is being tried out in the United States on a small-scale experimental basis. It enables each user to do the following: call certain pre-selected numbers by dialling two digits instead of the usual seven, have incoming calls routed to another phone when the line is being used, dial a code which causes all subsequent incoming calls to be automatically transferred to another number (to a friend's home. for example, if one went there for an evening), and dial an extension that is on the same line but in a different location (enabling the use of extensions for an intercommunication system).

Other features which are to be added shortly will make it possible to do two additional things: dial a three-way hook-up, and wait when there is a "busy" signal until the busy telephone is available.

The experimental test is being carried out with 300 telephones in the town of Morris, Illinois. The Bell Telephone Laboratories, developers of the system, state that the first production models will be operating by mid-1965 and will be introduced gradually thereafter as the need arises for replacements or expansion.

The key elements in the system are memory units which store 2¼ million "bits" of information. These consist of four plates like the one shown here; the "bits" are dots that are produced photographically on the squares of film and are "read" with a scanning spot of light from a cathode-ray tube. The entire memory can be scanned in one-ninth of a second and a particular item can be read out in a few microseconds.

The system is also self-checking. When it discovers a fault, it locates and diagnoses the trouble and, in some cases, even makes the necessary corrections. If the fault cannot be corrected by the unit itself, it notes the trouble on a teletypewriter for a repairman.

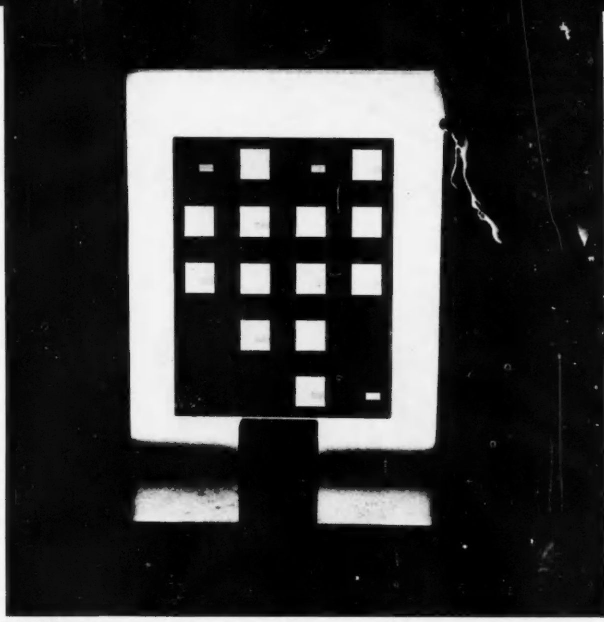
Although some of the basic theory on which the unit is based has been known for many years, the system became feasible only with the advent of transistors and other semiconductors and the development of high-speed, high-capacity memory systems.

NEW TECHNIQUES FOR STUDYING BLOOD VESSEL SYSTEMS AND RESTORING HEART ACTION

A technique for obtaining plastic replicas of blood vessel systems and a simple technique for restoring heart action without surgery, drugs, or electric shock have been announced at two research centres in the United States.

The former was developed under the cardiovascular research programme at the Los Angeles County Hospital. By forcing a plastic through blood vessel systems from the lungs of animals, scientists there report they have obtained completely accurate reproductions of lung capillaries that are so small only one corpuscle can squeeze through at a time. It is in these microscopic blood vessels that the blood exchanges carbon dioxide for oxygen and since the impairment of this exchange process is often the cause of cardiac ailments, a better understanding of the capillary system may lead to the more rapid development of remedial measures. A number of plastic casts are now being studied to determine the differences between normal and abnormal pulmonary systems and the effects of diseases.

The technique for restoring heart action without the use of surgery, drugs, or electric shock was developed at Johns Hopkins University, Baltimore, and consists simply of a rhythmic application of pressure to the lower breastbone. The patient is placed on his back on a floor or table and the operator pushes firmly on the breastbone every second or so with the heel of one hand, his other hand on top. Since the ribs are attached to the sternum with flexible cartilage, the chest can be compressed, squeezing the heart between the breastbone and the spinal column and forcing the blood out of the ventricles of the heart. It has been found advantageous

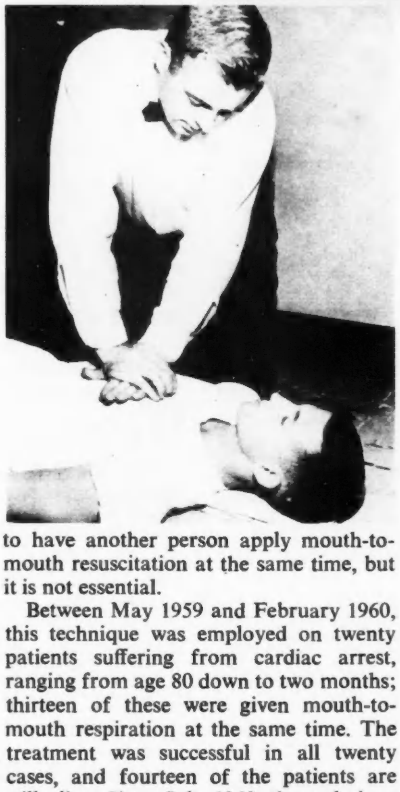


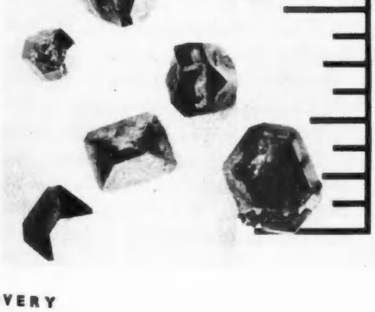
(*Above*) Plastic casts of the blood vessel systems in the lungs of various animals.

(*Top right*) Photographic memory plate used in experimental Bell Telephone system.

(*Right*) Demonstration of a non-surgical technique for re-starting heart action or correcting ventricular fibrillation.

(*Below*) Largest man-made diamonds yet produced —a carat-sized collection made at the General Electric Research Laboratory, U.S.A.





to have another person apply mouth-to-mouth resuscitation at the same time, but it is not essential.

Between May 1959 and February 1960, this technique was employed on twenty patients suffering from cardiac arrest, ranging from age 80 down to two months; thirteen of these were given mouth-to-mouth respiration at the same time. The treatment was successful in all twenty cases, and fourteen of the patients are still alive. Since July 1960, the technique was used on an additional thirty-five patients; of these, three out of four survived without any damage to the central nervous system. Where it has been used in the operating theatre, the method has been 100% effective.

Although the technique has aroused some scepticism among members of the medical profession in various countries, the researchers report that medical men who have seen it demonstrated and have studied its effects consider it a major development. There is particular interest in it as an emergency measure that can be used by laymen when a doctor cannot be reached in time.

ERWIN SCHRÖDINGER

Prof. E. Schrödinger, the author of wave mechanics, died on January 4. His greatest contribution to physics is contained in a series of five papers, published between March and September 1926.

At that time, the old ideas of physics had been shown to fail in their applications to phenomena on the atomic scale. The bold idea of Planck about the quantum of action—which he had invented to deal with the problem of the equilibrium between matter and radiation—had been applied by Niels Bohr to the motion of electrons in atoms and had brought a large degree of order into the mysteries of atomic spectrum. But Bohr's quantisation rules, which had been refined by Sommerfeld and others, were, in spite of their success, only calculating rules superimposed on classical mechanics and were apparently incompatible with it. The logical structure of atomic dynamics was therefore unsatisfactory and even the rules for calculation were unambiguous only for special and very simple situations. Something fundamentally new was clearly required. The final step which turned quantum theory into a firm and consistent scheme of mechanics resulted from two independent and, at first sight, very different approaches. The "matrix mechanics" of Heisenberg and others came first, but its impact on physics was not as immediate as that of Schrödinger's work.

continued on page 85

THE EARLY DEVELOPMENT OF THE PARENT-CHILD RELATIONSHIP

R. A. HINDE

Adequate food, warmth, and cleanliness are not enough to make a happy child. The personality of the growing infant is developed through interchanges with those around it, of whom the mother is the most important. Indeed during its first few years of life, the child forms a relationship with its mother that is of fundamental importance for its later development.[4] For a full understanding of the human personality, it is essential that we know how this relationship is formed; since each stage of a child's development depends on preceding stages, we must try to trace the mother-child relationship back to its earliest beginnings.

Parental care is not, of course, peculiar to our own species. In nearly all mammals and birds, in many fish and in some species from other groups it has been elaborated to the point where a relatively long-lasting relationship is established between parent and young. In some cases, this bond may affect the animal's behaviour throughout its life.

The ancestor common to birds and mammals must have lived about 200 million years ago. Although parental care has evolved independently in the two groups, resulting in different mechanisms of parental behaviour, the problems involved are essentially similar, just as the wings of bats and birds, though differing fundamentally in structure, depend on similar aerodynamic principles. Thus, while an understanding of the parental behaviour of lower forms cannot give us a direct understanding of our own, it can provide valuable principles and techniques with which to start an analysis.

R. A. Hinde is Curator of the Sub-department of Animal Behaviour at Cambridge University and is a Fellow and Tutor of St John's College. He is currently engaged in research on various aspects of animal behaviour, working especially with birds and monkeys.

INSTINCTIVE RESPONSES

The relationship between a human mother and child is, of course, one of enormous complexity but recent evidence suggests that, like those of lower vertebrates, it is built on a basis of relatively simple responses. These therefore provide a proper starting point for its analysis.[5]

In the first place, studies of the stimuli which elicit responses given by parents to their young, or by the young to their parents, usually show that the parent does not respond to its young as a whole but only to a small selection of the stimuli which it presents, and vice versa. When an adult bird is putting food into a nestling's mouth, for example, it is responding primarily to the conspicuous colours of the gape, and the rest of the nestling is apparently of little importance. The parent will feed an artificial gape as eagerly as it feeds its own young even though the gape lacks all the other characteristic features of a nestling bird[3] (Figs. 1–3). In fact, artificial gapes are used by ecologists who wish to identify the food which birds bring their young.

Similarly, a young cuckoo just out of the nest is often fed not only by its foster-parents but by a variety of other adult birds as well. Its large gape provides—perhaps in exaggerated form—the stimuli relevant for feeding; its

Studies of animal and human babies are beginning to throw some light on how bonds are formed between a child and its mother. Smiling, crying, clinging, sucking and other simple responses, early learning, and the onset of fear and aggression all play their part. The parent-child relationship has a great influence on the development of the child's personality.

large size and unusual body shape are of little consequence.

The reverse of this can be seen in the behaviour of young Herring Gulls. The newly hatched chicks obtain food by pecking at the tip of their parents' beaks but will also peck readily at cardboard models (Fig. 4). By varying the properties of such models systematically, Tinbergen has shown that only certain characteristics of the bill are important; shape and colour of the head make no difference to the number of times a chick pecks.[17]

Similar generalisations hold for our own species. When the hungry newborn human is touched lightly in an area that includes part of his cheek and upper lip, he turns his head towards the point stimulated. When the baby is lying in its mother's arms, this movement facilitates the finding of the nipple.[13] Sucking also is elicited by a relatively simple tactile stimulus—by the nipple filling the mouth. As with animals, both of these responses can be obtained by models which lack many of the characteristics of the normal object.

It is not to be expected that the sophisticated human mother should respond to stimuli that are quite so simple as those described so far, of course, but there is evidence that certain features of babies are especially effective in provoking maternal responses—a protruding forehead and a shambling gait, for instance. This has been exploited by manufacturers of children's toys and by Disney in his cartoons.

The behaviour of parents to young and young to parents does not consist merely of simple responses to simple stimuli. At the very least, such responses are joined together into functional chains of behaviour. Thus a nestling Great Tit begins to beg by opening its mouth and giving a special call as soon as it hears its parents arrive outside the nest hole. On entry, the parent is stimulated to feed the young by the visual pattern of its gape. Contact between food and gape causes the nestling to swallow. It then turns round in the nest cup, raises its cloaca and defaecates, and the white faecal sac is picked up by the parent and removed from the nest.

The feeding of the human newborn similarly involves a chain of responses. The hungry baby turns its head from side to side. If it is lying in its mother's arms, this movement is likely to bring its head against her breast. Then, as we have noted, tactile stimuli on the circumoral area cause the baby to move its mouth towards the point stimulated, and adequate stimulation from the nipple inside the mouth leads to sucking.

EARLY LEARNING

So far, we have discussed these sequences of response as though they were quite stereotyped, but it is a safe assumption that every time such a sequence occurs, learning takes place which modifies its course on subsequent occasions. Many parent birds quickly learn to recognise their own young, and the young their parents. Kittens even learn to find one particular nipple out of those available to them during the first few days of life.[16]

Early learning is even more important in our own species.

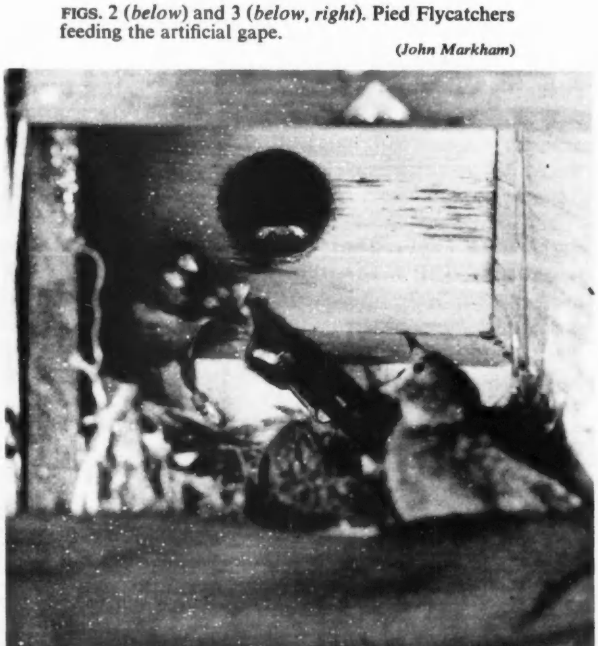
If a baby's first few feeds go well, it is likely that a satisfactory feeding relationship between mother and child will be established and last for the duration of the breast feeding period. If, on the other hand, there are difficulties, the situation may rapidly deteriorate. Such difficulties are commonly of two kinds. Sometimes the areolar tissue is insufficiently yielding to be sucked past the baby's gums. When this happens, the baby's palate is not fully stimulated and

(*John Markham*)

FIG. 1. Artificial gape used for collecting food brought by parent birds for their nestlings.

FIGS. 2 (*below*) and 3 (*below, right*). Pied Flycatchers feeding the artificial gape.

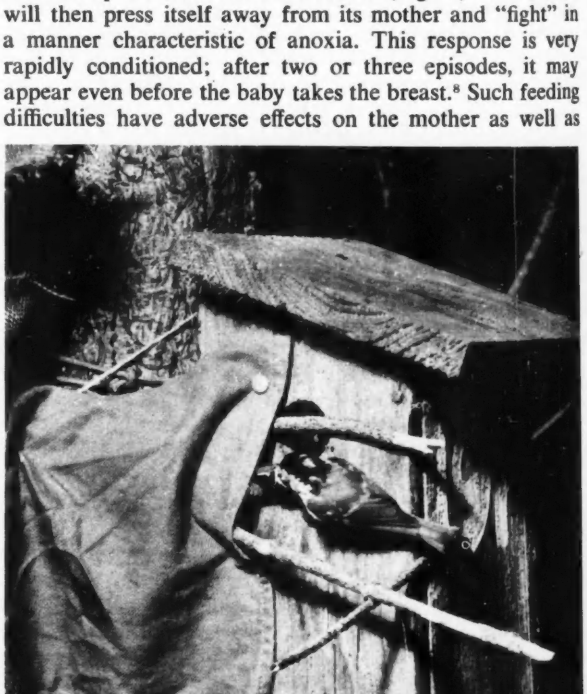
(*John Markham*)

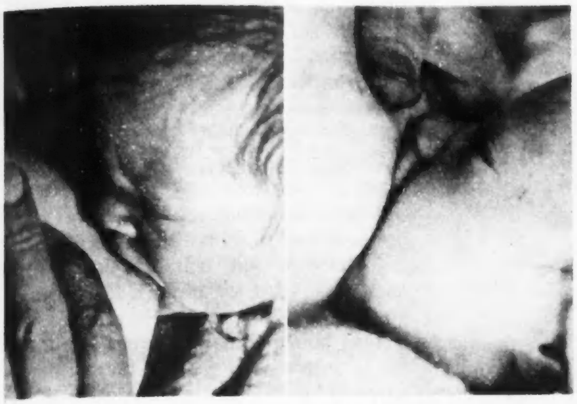


(*N. Tinbergen*)

FIG. 4. Cardboard model used for studying stimuli eliciting the feeding responses in young Herring Gull chicks.

sucking is apathetic; such babies may continue to suck lazily for weeks, making it difficult to establish a normal feeding pattern. A second possible difficulty may arise when the shape of the breast causes the baby's upper lip to curl up in front of its nostrils (Fig. 5). The child will then press itself away from its mother and "fight" in a manner characteristic of anoxia. This response is very rapidly conditioned; after two or three episodes, it may appear even before the baby takes the breast.[8] Such feeding difficulties have adverse effects on the mother as well as





(*M. Gunther*, The Lancet)

FIG. 5. (*Left*) Normal breast-feeding. (*Right*) Breast-feeding with the baby's upper lip pressed against its nose.

the baby. Apathy on the part of the baby or a fighting response will profoundly disturb the mother. She may become depressed and try to chivy the baby, or give up the attempt to nurse. She may even think she has already failed as a mother, and the seeds of a bad relationship may thus already have been sown.

FORMATION OF BONDS BETWEEN YOUNG AND PARENTS

Feeding may occupy only a small part of the time which parent and young spend together, of course. As a matter of fact, the most important bonds between mother and young seem to have little to do with the satisfaction of the physiological needs in a very wide range of species. In nidifugous birds such as domestic chickens and ducks, for example, the young are born in an advanced state and find food with relatively little help from their parents, even though they

FIG. 6. Young coot following a wooden box that is being pulled along a wire.

remain with the adults and are dependent on them for protection for several weeks.

The young of such species form a close attachment to their parents during a brief period after hatching. Thus, if a young chick hatched in an incubator is exposed to a moving object when it is about twenty hours old, it will follow the object as assiduously as it would its own parent. The characteristics of the moving object apparently matter little; many young birds will follow a walking man or a small cardboard cube with almost equal readiness (Fig. 6) and, indeed, some sort of attachment may even be formed with an intermittently flashing light.[11] If the chick is offered a moving object early in its life, it will follow it on all subsequent occasions until it has reached the age when it would under natural conditions have ceased to follow its own parent. The chick thus forms an attachment to an

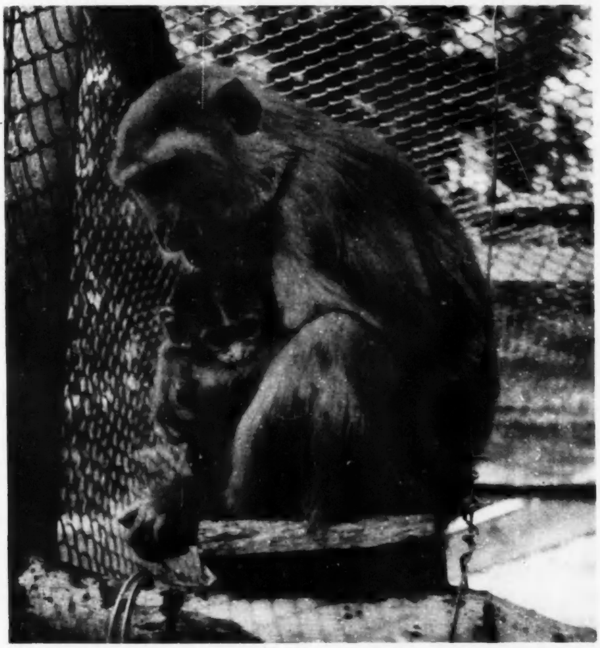


FIG. 7. Female rhesus monkey with three-month-old baby.

object which has never contributed to the satisfaction of any of its normally recognised physiological needs.

Harlow and Zimmermann,[9] attempting to find out what makes a good mother for a baby rhesus monkey, have come to a similar conclusion. In this species, the infant spends much of its early life clinging to its mother's belly (Fig. 7). Harlow's technique consisted of rearing the babies on inanimate substitute mothers. Some were made of wire mesh and others of a wooden cylinder covered with cloth (Fig. 8). In one series of experiments, each infant was provided with two substitute mothers—one of wire and the other covered with cloth. Half of the monkeys were fed only on one and the other half only on the other; yet all of the baby monkeys spent nearly all their time on the cloth mother, irrespective of where they were fed (Fig. 9). Those which were fed on the wire mother did not become progressively more attached to it—as would be expected if the

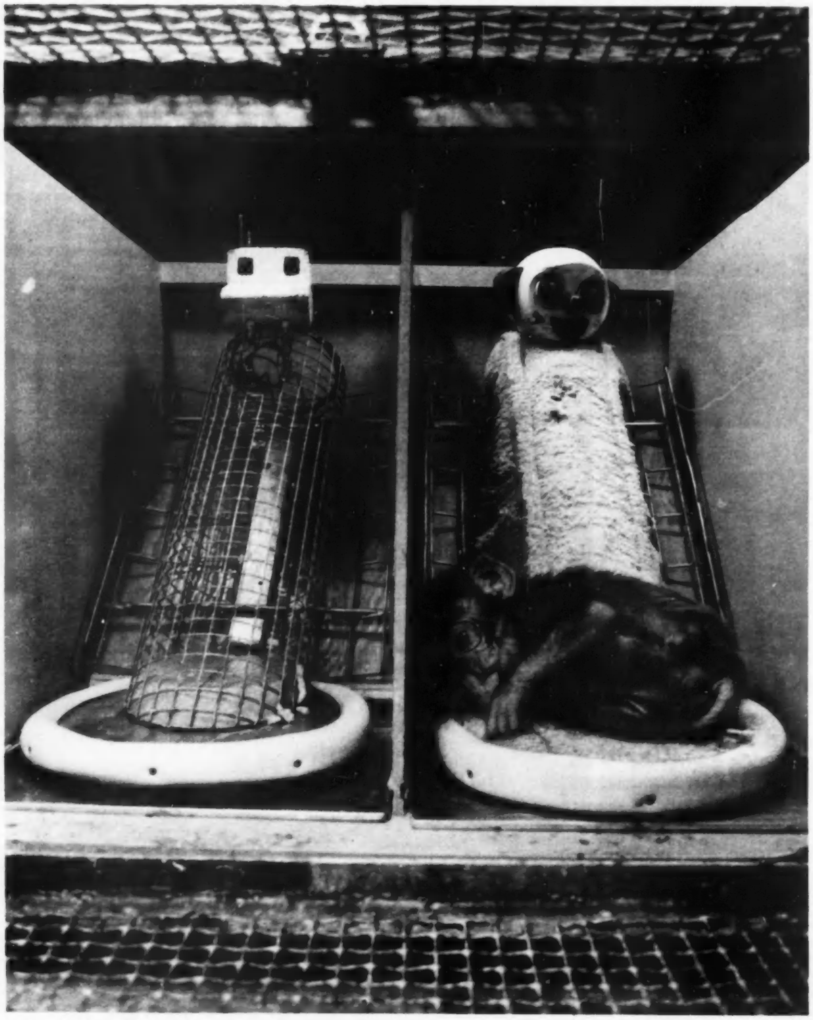


FIG. 8 (*left*). Substitute mothers used by Harlow for rearing young rhesus monkeys.

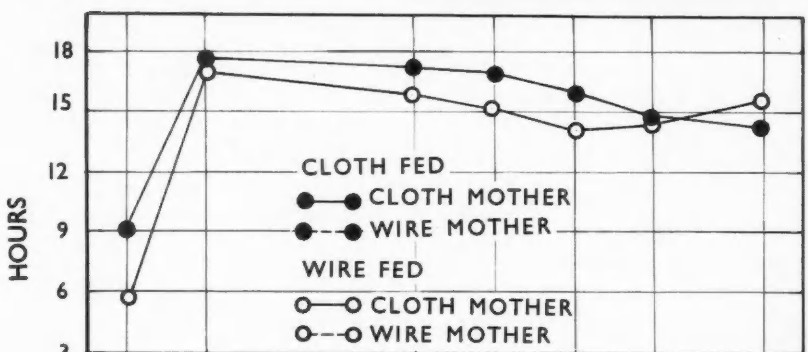
(*Fred Sponholz*, Science)

FIG. 9 (*below, left*). Record by Harlow and Zimmermann showing that all the infant monkeys spent nearly all their time on the cloth "mother". Those fed on the wire "mother" did not become attached to it.

(Science)

FIGS. 10 (*below*) and 11 (*below, right*). Frightening objects such as a mechanical Teddy Bear caused almost all infants to flee blindly to the cloth mother. Once reassured by pressing and rubbing against her, however, they would then look at the strange object.

(*Fred Sponholz*, Scientific American)



satisfaction of physiological needs were the fundamental issue—but spent their time on the non-lactating cloth mother. This suggests that the "contact comfort" provided by the cloth is of critical importance in developing what Harlow calls "affectional responsiveness".

The infant monkeys were also tested in a number of other ways. When a fear-provoking object like a mechanical Teddy Bear was introduced into the cage, for instance, the young rhesus would immediately cling to the cloth mother, regardless of which mother it had been fed on (Figs. 10 and 11). Contact with this mother would bring a renewal of courage; after a while, the baby would start to look around and make investigatory movements towards the fear-provoking stimulus. Babies which never had contact with a cloth mother, having been reared with only a wire one, ran towards their mother when shown a fear-provoking stimulus but did not cling to her. Instead, they clutched themselves and rocked their bodies to and fro, or rubbed themselves against the side of the cubicle for the remainder of the test.

These and many other experiments carried out by Harlow show that "contact comfort" is an essential factor in the formation of a bond between a baby rhesus and its mother and, in fact, that it is more important than the provision of food. Most pediatricians agree that physical contact between mother and baby are important in our own species also, and encourage the mother who feeds her baby from a bottle to hold it and cuddle it as though it were feeding from the breast.

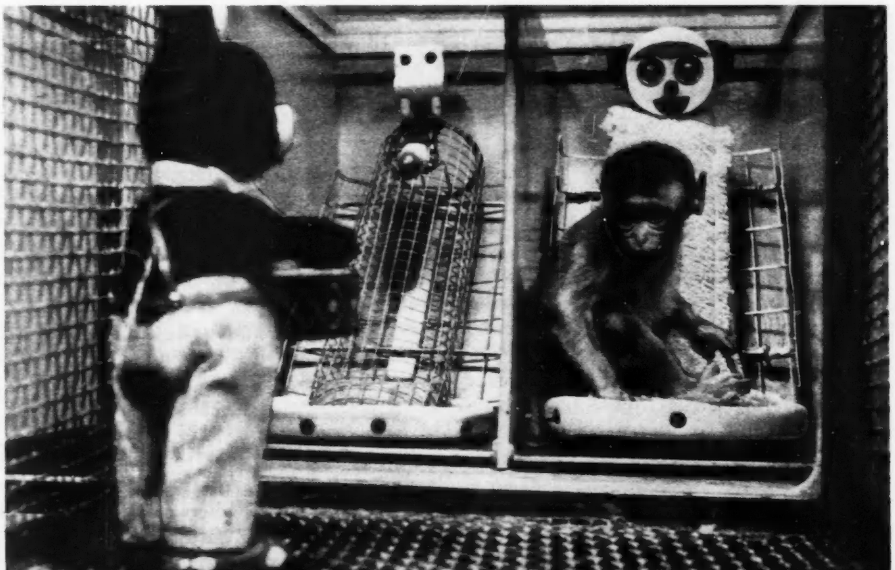
SPECIAL MECHANISMS FOR INCREASING COMMUNICATION—SMILING

Special mechanisms have evolved—in our own species, at least—whose primary function seems to lie in increasing the communication between mother and baby with no immediate relation to the satisfaction of physiological needs. The best-studied of these is the smile. It is similar to the instinctive patterns of lower forms in that it is a movement characteristic of the species whose appearance in a co-ordinated form during *early* life does not seem to depend on imitation or reward. In these respects, it resembles the movements used by the human baby to find the nipple and suck.

The stimuli which elicit smiling are simple at first. During the second month, dots or groups of dots make a baby smile more readily than a detailed representation of the human face, probably indicating that the eyes a baby sees are the fundamentally important stimuli. After about two months, however, eyes alone become less and less effective; more of the details around the eyes and, later, the whole face are needed to elicit a smile.[1] Later still, the infant smiles only at its own mother and at a small group of other familiar individuals.

Little is known at the present time about the precise function of smiling in a baby's life but it has both short and long term effects on the bond between mother and child. Although it does not elicit any particular response in the mother, it affects her mood, making her more sympathetic to the baby's needs. When the baby smiles, she often picks it up and cuddles it and it is possible that the principal function of smiling is to provoke this maternal response. The baby's movements as it smiles provide further evidence for this view. It often turns towards the mother, arches its back, and moves its body and limbs. When it is picked up, the smile disappears, as though this were the result at which the smile was aimed.[2] The cumulative effect of the baby's smiles on its mother is not limited to a brief change of mood, of course, but has long term effects on her feelings about it. That such effects may be reciprocal is shown by Brackbill's observation[6] that infants smile more if they are regularly picked up and cuddled after smiling.

We see, then, that relatively simple stimulus-response



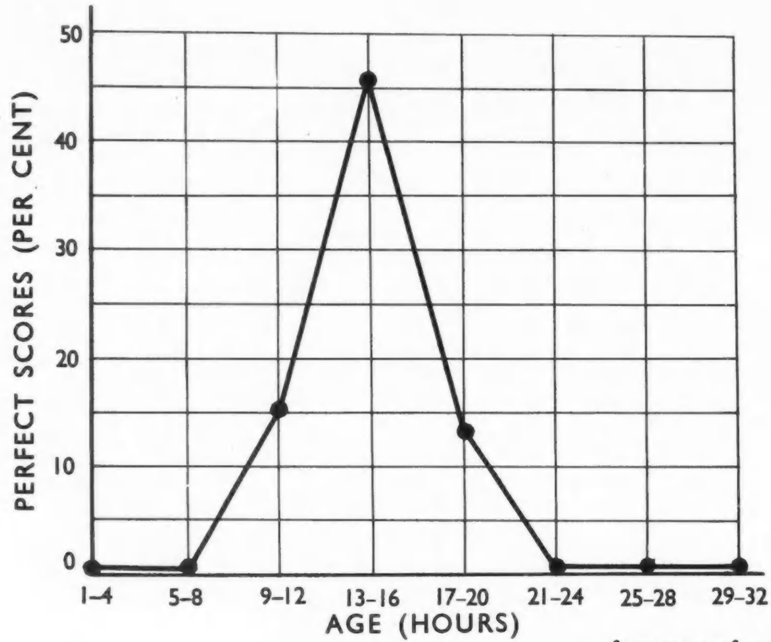


FIG. 12. Record by Hess showing sensitive period for imprinting of the "following response" in chicks.
(Science)

actions play a fundamental role in establishing the relationship between parent and offspring, although these actions may be elaborated into patterns of behaviour which involve a reciprocal interaction between the two. These patterns of behaviour may be modified by learning in which the reduction of physiological needs does not play an essential role.

SENSITIVE PERIODS OF LEARNING

A further characteristic of this learning is that it is most likely to occur during a relatively brief "sensitive period". The imprinting of the "following response" of chicks, for example, is likely to occur only if exposure to the moving object is made when the bird is more than a few hours old and less than two days old (Fig. 12). The lower limit is probably set by the development of locomotor and perceptual abilities in the young bird.[10] There is still some argument over the factors which set the upper limit but it seems probable that the forty-hour old chick fails to follow the model because by this age strange objects and situations evoke fear or anxiety responses which are incompatible with following.

In a similar manner, the learning which accompanies the responses involved in the interaction between a human mother and her baby is most likely to occur during particular sensitive periods. For the sucking response, this extends only over the first four or five days of life; if the mouth is not filled with a stimulus object of the appropriate size during this period, there may be protracted feeding difficulties. With smiling, the sensitive period lasts from about the end of the first month until about twenty weeks; during this period, the infant learns to smile at familiar faces and ceases to smile at unfamiliar ones. The onset of the period seems to be determined by the development of the ability to fixate the stimulus; the waning of the smiling response to strange faces is probably related to the reinforcement of smiling by the mother and non-reinforcement by strangers, together, perhaps, with a gradual development of fear of strangers.[2]

FEAR OF SEPARATION

Once the bond between parent and offspring has been established, the parent becomes an essential part of the familiar environment of the infant. If she disappears, the young animal will do all in its power to regain contact, using a special form of appetitive behaviour which has evolved for this function. In the chick, this consists of locomotion coupled with high pitched "distress" calls which bring the mother to its aid.[7] The rate at which distress calls are given is reduced by warmth, contact, and other stimuli normally provided by the mother. Young mice placed outside the nest give a supersonic squeak which causes the mother to retrieve them.

Crying plays a similar role in our own species. During the first few months, there seems to be no difference between the cries given for hunger, attention, or other needs, but they later become differentiated.[12] Although babies cry for many reasons, separation from the mother is one of the most frequent causes: mere sight of the mother or actual contact may appease the crying, depending on the degree of the child's distress from other causes. Crying, like smiling, does not elicit a specific response from the mother: although it does not necessarily make her feel more kindly disposed towards the baby, she usually takes steps to stop its crying.

THE ONSET OF FEAR OF, AND AGGRESSIVENESS TOWARDS, ADULTS

Although we have so far emphasised the bond of affection between parents and offspring, the relationship between the members of a family is always an ambivalent one. In animals, this ambivalence between attachment, fear, and aggression can be understood on functional grounds.

Normally, the young learn to recognise their parents individually and form a positive bond with them before they develop fear responses. In fact, if fear appeared too early, the formation of a bond with the parent would be impossible.

In many species, however, adults soon learn to recognise their own young and attack those of others, so that it becomes important for the young to flee from strange adults. They must also avoid objects that look strange or move in a strange way: this increases their chances of escaping from predators.

Later, when the young begin to be independent, they may in their own interests show a limited aggressiveness towards other members of their species or even members of their own families who become competitors for food and other natural resources. Later still, reciprocal aggressiveness between the young and their parents may appear when the young assume the characteristics of a rival adult.

Although the springs of ambivalence in the human relationship are very much more complicated, the same sequence of development is seen—first, the formation of a positive bond, then the appearance of fear, and then aggression.

THE FAR-REACHINC CONSEQUENCES OF EARLY EXPERIENCES

Since each stage in an organism's development depends on preceding stages, early experiences are likely to have far-reaching consequences. The special significance of the relationship with the mother—stressed by Greek dramatists and psychoanalysts alike—is not found in humans alone. In many birds, the choice of an adult sex partner is governed partly by the nature of the parent. Hess[10] showed this by rearing a jungle cock by hand, keeping it away from other members of its own species for its first month of life. Although the bird spent much of the next five years with other jungle fowl, it would court only human beings, not members of its own species. In such cases, the abnormal sexual relationship is due to the animal's responsiveness to stimuli to which it has become attached in the context of its relationship with its "parent".

Sometimes the animal responds to a complex of stimuli, some of which are recognised as a result of early learning, and some of which have meaning even though they have never been seen before. For instance, Räber[14] has described the case of an adult turkey cock that was reared by hand which courted men, attacked women, but copulated with objects the size of a turkey cock lying motionless on the ground. The discrimination between men and women was due to the flapping clothes and handbags of the latter although men who carried brief-cases were also attacked. Räber suggested that such objects fill the role of the wattles and drooping wings of a displaying male turkey and turn a human (responded to as a member of the turkey species as a result of early learning) into a rival.

CONCLUSION

We see, then, that there are many parallels between the relationship of woman to baby and the comparable relationship in lower forms of life. It must be emphasised again that these are parallels only at a descriptive level of analysis; the actual mechanisms may be very different. Human behaviour is more plastic and thus less predictable than that of animals; maternal behaviour in humans depends more on the previous experience of the individual. The human mother, like the chimpanzee but unlike a lower mammal, does not know how to look after her baby "instinctively", though, as we have seen, responses in which learning plays little part are important in her interaction with the child.

Many other types of behaviour in addition to those discussed here also play a part in the relationship—caressing, echoing maternal words, and so on. Complicated as the relation between mother and baby may be, however, it seems to rest on a relatively simple foundation. This does not in any way detract from its beauty but does raise the exciting possibility that this bond—of such vital importance to the development of the personality—may be susceptible to analysis.[5]

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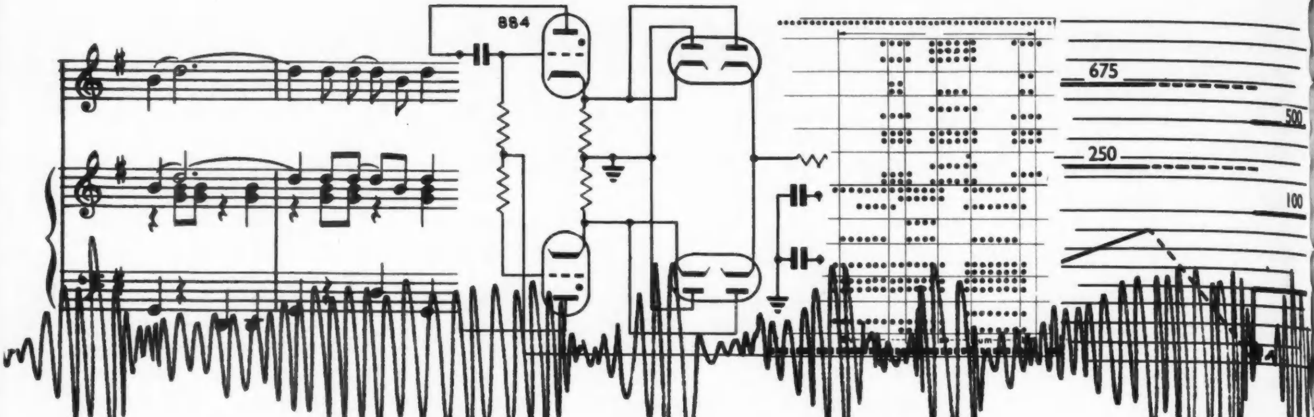


THE ELECTRICAL SYNTHESIS OF MUSIC

ALAN DOUGLAS

Electronic devices are opening up new possibilities in the long-static realm of music by freeing composers from the limitations inherent in conventional instruments and giving them unique sounds. With these new techniques, we may be on the threshold of a new era in music.

It is commonly stated that art reflects the spirit of the age in which it is born, and this has always proved to be true. But music is a special form of art which has two distinct divisions—the process of composing, and the development of instruments on which to perform such compositions. The art of composition has outpaced instrument development for a long time; in recent years, we find certain composers hard pressed to find instruments capable of interpreting their ideas.

Although it has been known for half a century that electrical methods can be used to simulate conventional musical instruments, the problems of instability and uncertainty of control have not made it advantageous to employ these methods. Investigators and inventors were unable to fully develop their ideas because the solutions to the problems of stability and control, though foreseeable, were not yet in hand. This was the situation until World War II. Military communication requirements during this period resulted in the development of electronic devices with calculable parameters and a high degree of stability, and this, in turn, led to the development of electronic tone sources that function predictably, opening the door to seemingly limitless possibilities.

Alan Douglas is the author of four books on electrical music and allied instruments and has contributed over one hundred papers to technical and musical journals on the subject.

Why is it desirable to enlist the aid of electronics for musical purposes? To properly answer this question, we must first consider the defects of conventional tone producers. As is well known, every musical instrument produces, in addition to its fundamental note, overtones or harmonics which enable us to recognise different instruments when we hear them. These instruments also produce noise, however, since it takes far less power to maintain resonance than it does to produce it. As it is not convenient, and in many cases impossible, to reduce the exciting force once a note has been started, the surplus energy results in noise.

Power and range are limited because there are restrictions on the physical proportions if the instrument is to "speak" properly. We must therefore use more instruments to obtain more power and different kinds of instruments for different pitch ranges (not to be confused with different tone qualities).

What seems to be the most serious limitation is the fact that all instruments with keys must employ an equally tempered scale to permit the transposing of music into all keys. (In an equally tempered scale, the frequency goes up with each step by the factor $\sqrt[n]{2}$ where n is the number of steps in each octave.) Fig. 1 clearly shows the discrepancies between the harmonics of one note (in this case lower A) and the other notes. For example, the seventh harmonic of lower A is 385 c/s, but it does not correspond exactly to any higher note; the closest to it is the G in the fourth octave, but there is a difference of 7 c/s or 1·82%. Hence, there is an appreciable discord when these two notes are played.

All equally tempered instruments produce additional "inharmonicity" for other fundamental reasons. The piano is the worst offender because the frequencies of the partials of a struck string are not truly harmonics of the fundamental frequency and the partials progressively sharpen as their order increases. The inharmonicity is least in the middle of the keyboard, increasing towards the ends. Hence, chords played near the top and bottom are objectionable to the ear.

Let us now consider musical instruments which produce their sounds electrically. Although the organ is generally thought to be the first complete instrument using purely electronic tone-sources, this is not the case; the work

of Leo Theremin, Edouard Martenot, and Friederich Trautwein antedated the organ and will be discussed shortly. The organ, however, was the first instrument to drive home to the general public the possibilities opened up by electronics. This class of instrument is now produced in large numbers, and, as they have been described in the literature,[2] no space will be devoted to them here.

We should note one or two reasons why they do not exactly duplicate the sound of the pipe-organ, however—something that nearly all of them are supposed to do. Those accustomed to the pipe-organ know that the sound does not start instantly; the air cannot instantly charge the pipe and time is required to bring a massive air column into resonance. Furthermore, the sound does not stop instantly when the key is released, since it takes a short time for the resonance to die out. We cannot easily duplicate this characteristic by electronic means, especially since it varies from the low-pitched to high-pitched pipes.

In addition, the sound pattern radiated from a loudspeaker in the lower bass range is not like that from the bass pipes in an organ. It is not a function of power, primarily, but of dispersion of the sound field. Simulation becomes a matter of cost, in this case, since many loudspeakers—each lightly loaded—could duplicate the sound from a wooden bass organ-pipe.

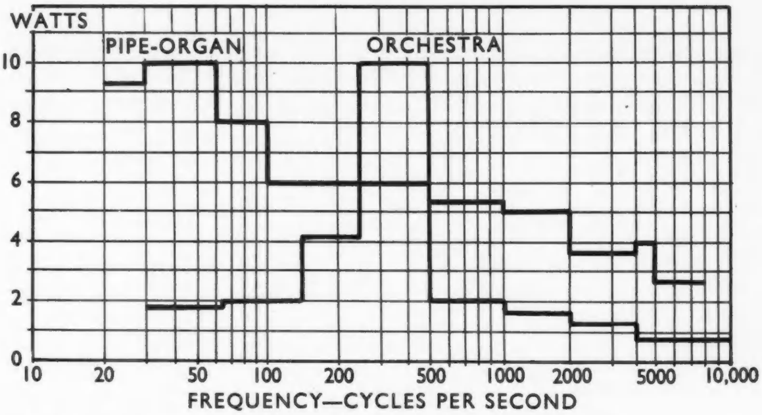


FIG. 2. Distribution of power in the sound radiated from a pipe-organ and an orchestra.

The distribution of power in the frequency spectrum of an organ is shown in Fig. 2. (That for a full orchestra is also shown for comparison.) In a few rare instances, electronic organs have been indistinguishable from pipe-organs; in most cases, however, they have been a more or less satisfactory compromise.

If we put the organ aside, we can dismiss the keyboard and forget about the need for equal temperament. We are then left with a field in which every parameter is flexible and controllable.

THE CREATION OF NEW SOUNDS

Let us first look at the ingredients required to form a conventional musical sound. There must be:

1. A pitch or fundamental frequency.
2. A duration of time.
3. A loudness level (not necessarily fixed).
4. A way in which the sound starts and another way in which it stops.

In addition, there may be:

5. Harmonics or overtones, often changing during the sounding time.
6. Vibrato or tremolo.
7. Noise due to the method of generation.

If we are interested in synthesising a known musical sound pattern, like that of the oboe, for example, all of these constituents must be qualitatively and quantitatively correct. The omission or variation of any one part will cause the auditory system to register irritation, for when we recognise an oboe, we try to hear an oboe and are irritated by something to which we are not accustomed. By long usage, the ear anticipates certain wave-shapes and is conditioned to receive and interpret them. However, one can very quickly become

FIG. 1. Comparison of the harmonics of the first A on a piano with the fundamental frequencies of higher notes, showing the differences that produce discord.[1]

Harmonic	*Natural Frequency*	*Nearest Note E.T. Scale*	*Frequency, E.T. Scale*	*Deviation c/s*	*Percentage Error*
1	55	A^1	55	0	0
2	110	A^2	100	0	0
3	165	E^3	164·81	− ·19	·115
4	220	A^3	220	0	0
5	275	$G\#^4$	227·18	+ 1·82	·662
6	330	E^4	329·63	− ·37	·112
7	385	G^4	392	+ 7	1·82
8	440	A^4	440	0	0
9	495	B^4	493·88	− 1·12	·226
10	550	$C\#^5$	554·37	+ 4·37	·795
11	605	$D\#^5$	622·25	+17·75	2·935
12	660	E^5	659·26	− ·74	·112
13	715	F^5	698·46	−16·54	2·32
14	770	G^5	783·99	+13·99	1·82
15	825	$G\ ^5$	830·61	+ 5·61	·68
16	880	A^5	880	0	0
17	935	$A\#^5$	932·33	− 2·67	·286
18	990	B^5	987·77	− 2·23	·226
19	1045	C^6	1046·50	+ 1·50	·147
20	1100	C^6	1108·73	+ 8·73	·793
21	1155	$C\#^6$	1174·66	+19·66	1·7
22	1210	D^6	1244·51	+34·51	2·85
23	1265	$D\#^6$	1244·51	−20·49	1·62
24	1320	E^6	1318·51	− 1·49	·113
25	1375	F^6	1396·91	+21·91	1·159
26	1430	F^6	1396·91	−33·09	2·38
27	1485	$F\#^6$	1479·98	− 5·02	·338
28	1540	G^6	1567·98	+27·02	1·815
29	1595	G^6	1567·98	−27·02	1·760
30	1650	$G\#^6$	1661·22	+11·22	·681
31	1705	$G\#^6$	1661·22	−33·78	1·98
32	1760	A^6	1760	0	0

accustomed to different sounds if they are not too loud and the wave-shape has not been purposely distorted. As soon as a sound has been repeated for a few wave-trains, the initial sensitivity of the ear is greatly reduced and the ear becomes "accustomed" to it. The "attack", or the way in which a sound starts, is therefore of paramount importance. A sound cannot readily be identified if it is deprived of its characteristic attack; this, in fact, is a way of creating new tone-colours.

New sensations can also be obtained by altering the decay of a sound. The decay is not as critical as the attack, however, for the ear is retentive and is slow to give up the sensation of sound. We can tell very quickly when a sound starts, but we cannot tell exactly when it ends. This is easily demonstrated with a record-player that can run backwards. When a guitar recording is played in the normal way, the percussive wave-front, Fig. 3A, is heard as a loud sound. In reverse, Fig. 3B, the effect is quite different. The sound does not seem to cut off with the same vigour with which it started, though the change in volume is the same.

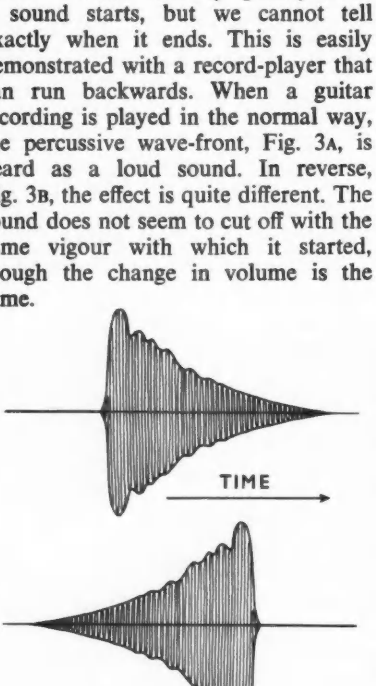


FIG. 3. A: Wave-form of normal guitar note. B: Wave-form of guitar note when played backward on a record player.

New sensations can be produced not only by modifying the attack and decay of sounds but also by adding harmonics. Although there appear to be an infinite number of possibilities in the number and loudness of the harmonics that can be introduced, the results obtained are actually disappointing because the ear always tries to match new sounds with ones it knows. Thus, it is difficult to produce steady tones that sound new. However, many very novel effects are possible by starting with pure tones and shaping them into percussive sounds. The ear must hear a sound for some 0·01 to 0·02 sec. in order to identify it. If we can shape the front of a sine wave within this time, it will have a new quality, and if, as the ear is getting accustomed to it, we shape the tail end of the wave in a different way, we will stimulate the ear again. Although it is impossible to convey the nature of a sound on paper, the range of variation possible is illustrated in Fig. 4. A large number of remarkable effects are possible with wave-shaping techniques and many have been used by Oskar Sala in Germany; his *scherzo étude* for Trautonium is a good example.

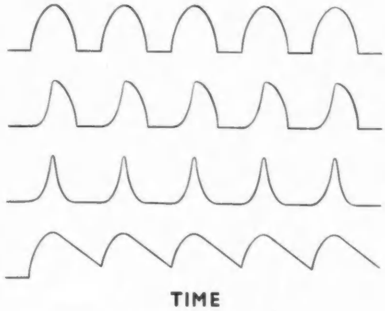


FIG. 4. Some of the percussive wave-forms that can readily be obtained with wave-shaping electronic circuits.

Of all the conventional sounds in music, the percussion group have been the most poorly developed. Conventional percussion instruments include atonal devices that are mainly rhythm markers (cymbals, triangle, and side drum) and tuned resonators (the celeste, glockenspiel, xylophone, and tuned tympani). There is a wide gap between the high notes of the glockenspiel and the low notes of tuned tympani that can be filled excellently with electronic percussions which can cover the entire audible range.

THE USE OF NOISE

Noise provides an unavoidable accompaniment to many musical sounds. Almost everyone has heard the peculiar sounds produced on telegraph wires by the wind or the strangely odd sound of the Aeolian harp. These eerie tonalities can be turned to valuable use in music. If the electrical signal from a "white-noise" generator (for example, a gas tube discharge) is fed into filter circuits that pass only the 6000 to 12,000 c/s frequency band, and the result is then put into a loudspeaker system, it will sound like a high-pitched hiss. When a pure tone, a musical sequence, or chords are superimposed on this, however, a new kind of sound results with a pleasing tone pattern. Some examples have been recorded at Radio Bremen.

EQUIPMENT FOR SYNTHESISING SOUNDS

In order to synthesise music with the desired quality and quantity of noise, attack, decay, and so forth, it is necessary to have a versatile electronic generator. The Trautonium[3] fulfils all the necessary requirements and is, in addition, stepless, having a sliding scale. To assist in the location of the major chromatic intervals, dummy rubber keys are fitted above the upper clavier. The technical possibilities with this device are immense.

It consists basically of two separate sawtooth wave-generators with circuits for tone-shaping, and frequency-dividing circuits[4] to produce sub-harmonics. Foot pedals control the loudness of each clavier. The model shown in Fig. 5 is a self-contained concert instrument with all the controls needed to synthesise music.

With a number of Trautoniums, an entire orchestra employing conventional tone-colours, new sounds, or a mixture of both can be simulated. In fact, by producing reverberation effects electrically, there is even no need for a studio or auditorium with desirable acoustic properties. A programme can be recorded in a small room with a great saving of expense. The apparatus in use at the Cologne studios of NWDR is shown in Fig. 6.

WRITING MUSIC FOR ELECTRONIC INSTRUMENTS

With the removal of conventional restrictions on tempo, tone-colour, loudness, attack and decay, and so forth, it is no longer necessary to write music with conventional notations. It now becomes possible to use a more flexible

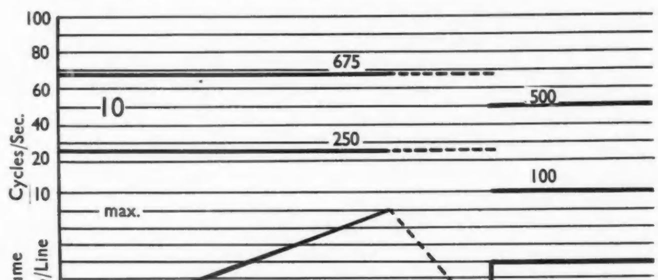
FIG. 5. Oskar Sala at his concert Trautonium.

and informative method, for we are no longer limited to tonal intervals in the scale.

Pitch and duration are plotted in the frequency-time plane, as shown in Fig. 7. The entire frequency range can be covered by using a 10 to 100-frequency scale and a multiplying factor in place of the key signature, a 10 in this example. The dynamic or power range is plotted in the volume-time plane. When the sound is to fade out, this effect is represented by dotted lines.

When it is desirable to modulate one kind of sound with another, the two sets of sounds are written down separately with instructions for the kind of modulation to be used. When noise is to be added, this can be shown by a frequency band-time plot.[8]

FIG. 7. Typical form of musical notation for electrical instruments.



Whilst we do not wish to devote too much space to technicalities, mention should be made of an ingenious device for compounding new tone-colours that was invented by Dr H. Le Caine of the National Research Council of Canada. As each note is played with the right hand, electronic generators feed a variety of wave-forms at that frequency into segments of a plate, like that shown in Fig. 8; sine waves, pulse trains, sawtooth waves, square waves, and any others that are desired are fed into the segments simultaneously. The composer can then choose any combination of these by moving a disc connected to an amplifier over the segmented plate. The disc is coated with a thin layer of insulation so that the relative amount of each type of wave-form that gets to the amplifier depends on the capacitive coupling and is proportional to the area covered. Loudness can also be altered

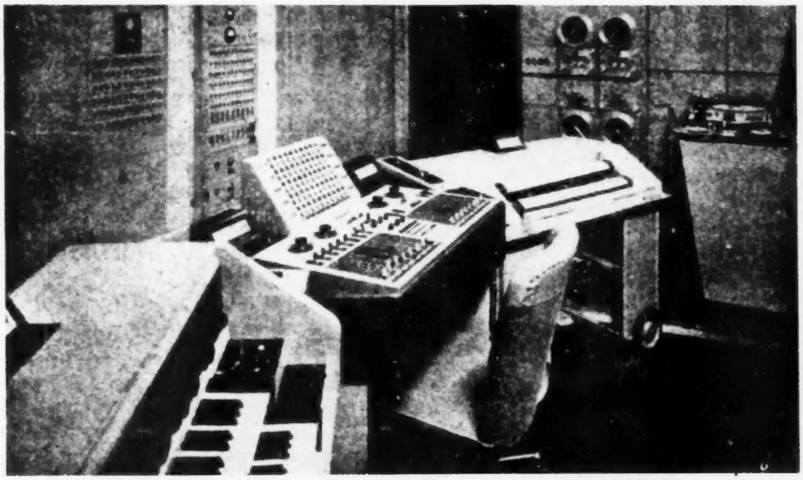


FIG. 6. Equipment for synthesising music at the Cologne studios of NWDR. Apparatus on wheels is a Trautonium.

by lifting the disc. With practice, some remarkable tone qualities can be synthesised. By using all the wave-forms except the pulse, for example, a full bold trumpet tone results. When the disc is drawn away from the segment with the sine wave, the tone hardens. As the pulse is approached and the sawtooth and square wave are left behind, the tone becomes hard and piercing. Such striking changes in brass tone-colour cannot be made as quickly or effectively with any conventional instrument. Many interesting experiments

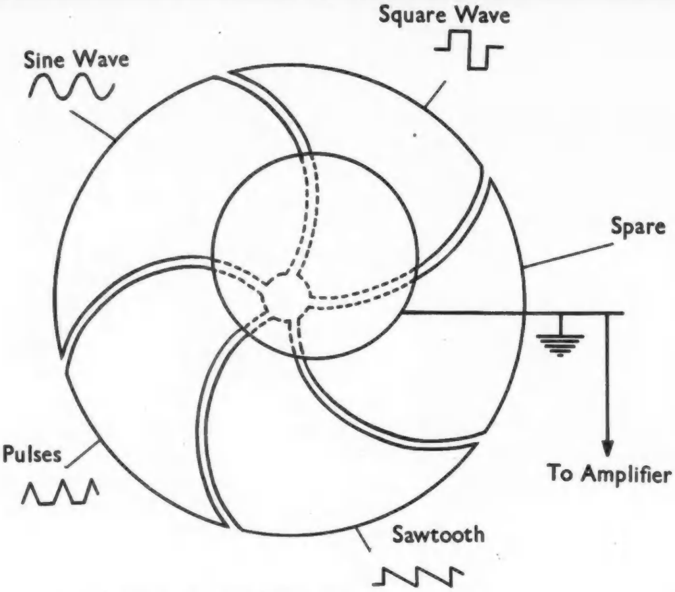


FIG. 8. Mixing device of Dr H. Le Caine.

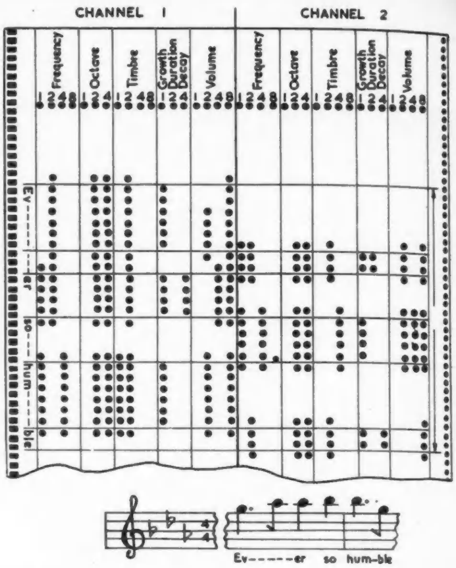


FIG. 9. Perforated strip for RCA's automatic music generator with corresponding conventional notation below it.

with the starting and stopping of sounds can also be made with this device if one has enough dexterity.

Many difficulties have been encountered in the development of instruments in which touch and attack can be varied. Although the circuits of such early investigators as Leo Theremin[6] and E. Martenot[7] are interesting, they have not proven suitable for commercial production. Interested readers can refer to their patents.

MUSIC WITHOUT MUSICIANS

Every means so far described for either tonal synthesis, composition, or even direct playing requires the services of a skilled performer. It was only to be expected that research would be carried out on mechanical means for doing these things. The only successful mechanical system so far is the one developed by the Radio Corporation of America,[8] although Coupleux and Givelet[9] of France started working on the idea back in 1930. The RCA scheme utilises a perforated paper strip that is divided into two channels, Fig. 9. The pitch or frequency of the notes is punched in the first column along the left-hand side of each channel; four rows of holes permit 16 notes in each octave. Three rows of holes in the second column make it possible to choose any one of eight octaves. Thus, 128 notes are possible over the entire range. A note is sustained by punching a series of holes in the vertical direction; each hole allows a microswitch to close, and the switches are designed so that they will not open if another hole follows immediately.

The holes punched in the other columns affect volume, timbre, and wave-shape, and can produce either conventional or new sounds. As only two channels are provided, complete scores have to be recorded in groups of two notes and superimposed. Some examples of this ingenious and versatile instrument are available on an RCA-Victor record, LM 1922.

One of the advantages of this device is that a composer can work out the elements of, say, a string quintet and immediately punch a paper roll and hear how it sounds. He can then revise his harmonies, tempo, expressions, and so forth, until he is satisfied —all without the use of a single musician.

Many other electronic devices can be used for playing or composing music, of course. At the Philips laboratories, H. Badings[10] has a multivibrator circuit (a square-wave generator) arranged so that its frequency can be varied by inserting the finger in a ring on a cord that is connected to the tuning element. With this device, continuously gliding tones or separate notes can be produced. M. Martenot has a rather similar device in which the tuning of a beat-frequency oscillator can be varied continuously or with keys. By using a ribbon capacitor with a logarithmic characteristic,[11] he obtains a configuration which makes it possible for the keys to be uniformly spaced.

We have not mentioned *musique concrète*, since it is not essentially a means for musical composition but, rather, a process of tape manipulation using existing sound patterns. Composing can be done with tape manipulation, however; an attractive tune fabricated from the sound of a single falling drop of water has been produced by the electronic music laboratories of the National Research Council of Canada.

With the limitations of conventional tone-sources overcome, a field pregnant with untold possibilities is open to the musician who can shed his prejudices and take full advantage of this new art-form.

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RADIATION AND MAN

The committee appointed by the Medical Research Council to report on the hazards to man of nuclear and allied radiations has now issued its second report. This 154-page document deals with the genetic and somatic effects of radiation, permissible doses, and the existing and foreseeable levels of exposure. The following synopsis was prepared by the Headquarters Staff of the Medical Research Council.*

This report, of the Committee originally appointed by the Medical Research Council in 1955 in response to a request from the Prime Minister, takes into account increases in knowledge of the effects of ionising radiations which have accumulated since their first report in 1956. (The Hazards to Man of Nuclear and Allied Radiations. Cmd. 9780.)

It follows the general pattern of the earlier publication. The main chapters review the general field of radiation and its biological effects, the levels of radiation that exist at present and those that may be expected to occur in the future; and the possible hazards of exposure to radiation are also assessed. The technical background is given in eleven appendices. The report indicates that, although a great deal of new information is available, there are still many gaps in knowledge of the effects of radiation, and that further intensive research is accordingly still necessary.

The report again emphasises the difficulty of assessing the significance of radiations in absolute terms. Instead it makes use of the dose of radiation received from natural background as a reference level. In the United Kingdom this dose is, on average, about 100 millirads/year. By comparison, the doses received both from the increased use of radiation in modern life and from radioactive fall-out are extremely small.

RADIATION, AND ITS EFFECT ON THE HEALTH OF THE INDIVIDUAL

Leukaemia. The mortality from this disease has been rising for over twenty years in all countries for which data are available; in England and Wales the death-rate from various forms of leukaemia was 17 per million persons in 1931, 42 in 1950, and 56 in 1959. Most of the recorded increase has occurred in the older age groups, and in great part may be accounted for by increased recognition of the disease as a result of improvements in the medical care of the elderly. However, there does seem to have been a real increase in the incidence, among younger people, of two forms of the disease, acute leukaemia and chronic myeloid leukaemia, and it is known that these two forms of leukaemia can be produced by high doses of radiation received in special circumstances. Nevertheless, until there is more evidence on the effects of lower doses, it will be impossible to assess directly whether any part of the increased incidence now being observed in the general population is due to increased exposure to radiation. All the evidence that is at present available suggests that other factors must be implicated and that the effect of radiation is likely to be relatively small.

Special studies have been undertaken to investigate the possible causes of the variation in the incidence of leukaemia in different regions of Great Britain. These investigations have shown that no single factor will account for the differences, and have led the Committee to believe that local differences in radiological practice or in the natural background radiation cannot play more than a very small part. In two of the cities in the United Kingdom which were studied in great detail the difference in radiation exposure was estimated to have accounted at most for about 1% of the observed difference in leukaemia mortality.

The most complete information on the relation between exposure to relatively high doses of radiation and the incidence of leukaemia in man is provided by two continuing investigations: the study of the incidence of leukaemia in Hiroshima and Nagasaki and the surveys which are being sponsored by the Medical Research Council on the incidence of leukaemia in patients treated by radiation for ankylosing spondylitis, a disease of the spinal column. In the populations exposed at Hiroshima and Nagasaki to heavy irradiation from the atomic bombs in 1945, there has been a significant excess of cases of leukaemia. It has also been demonstrated that the incidence of leukaemia decreased with increasing distance from the bombs; that is, with diminishing doses of radiation. Results from this study that have become available since 1956 have shown a peak incidence of leukaemia in 1951, 1952, and 1953; that is, during the sixth, seventh, and eighth years after exposure to radiation. Since that time the incidence has diminished, although in 1957 it was still higher than the expected frequency in a comparable non-irradiated Japanese population. This information is not inconsistent with the results from the survey of patients irradiated for ankylosing spondylitis, which has indicated that the increased risk of inducing leukaemia in these different circumstances is diminishing by the tenth to twelfth years after exposure. As a result of the important evidence from these studies, the Committee now feel that they can assert with some confidence that the increased risk of leukaemia following high doses of radiation would be likely to decline after the lapse of a decade, and that an individual once exposed is not at uniformly increased risk for the whole of the rest of his life.

The Committee have also reviewed the evidence on the possibility that radiographic examination of the pregnant woman's abdomen or pelvis may add to the small natural chance that her child might develop leukaemia during the early years of its life. The results of the earlier studies of the leukaemogenic effect of irradiation *in utero* have not

* "The Hazards to Man of Nuclear and Allied Radiations: A Second Report to the Medical Research Council", Her Majesty's Stationery Office, London.

been substantiated by subsequent extensive investigations. However, the possibility that a small risk exists has not been disproved, and it would therefore seem prudent to reduce radiographic examination of the abdomen and pelvis of the pregnant woman to the lowest practicable level.

Cancer. Recent evidence made available by the Tumour Registry in Hiroshima indicates that there is an excess in the death-rate from cancer among the Japanese survivors of the atomic bomb explosions, and that it is highest amongst those who were closest to the exploding bombs. It is too early to say whether this increase in mortality affects all forms of cancer and whether it has reached its highest point, but other evidence suggests that the average latent period for the induction of cancer following irradiation is more than ten years.

The effects of variations in dose-rate. The biological effects of a given amount of radiation are related both to the intensity of radiation, as measured by the dose given in a unit of time, and also to the length of time over which the exposure is spread. Knowledge of the frequency and types of radiation injury in man comes from situations in which relatively large doses of radiation have been received at high rates, as, for example, during radiotherapy or at the moment of the nuclear explosions over Hiroshima and Nagasaki. Recently, in a number of investigations of the somatic effects of radiation on mice, moderate as well as high dose-rates have been used. In these experiments it was found that the response to a dose of radiation given over a long period of time, that is, at a low dose-rate, was less than that to the same dose given at a high rate. If these experimental findings are extended and can be taken to be applicable to man, previous estimates of the effects of radiation at low dose-rates based on the assumption that such effects are directly proportional to the total accumulated dose, irrespective of the rate at which it is received, may prove to have been too high. The Committee feel that further study of this problem is of great importance because the radiation to which man is exposed from the natural background and from fall-out is received at very low dose-rates.

"Threshold" dose of radiation. The Committee stress that any general concept of a single "threshold" or minimum dose of radiation below which no effect will be produced is an over-simplification and therefore misleading. Although there is sufficient knowledge to allow an approximate assessment of the damage which might be expected from high and moderate rates of exposure to radiation, the likely effects of low rates of exposure can only be inferred in a rather tentative way. Accordingly, the Committee consider that it is prudent to continue to assume that even the lowest doses of radiation may involve correspondingly small, though definite, probability of adverse effect. They feel that, although this attitude may be unduly cautious, it is the only justifiable one in the present state of knowledge.

THE GENETIC EFFECTS OF RADIATION

The Committee draw attention to the increase in knowledge about human chromosomes and the demonstration, predicted in their 1956 report, that some hereditary diseases are associated with chromosome abnormalities. However, there is little evidence to indicate whether or not this type of abnormality can be produced by radiation, and it is considered wise, at present, to adopt a cautious approach to this problem.

In 1956 it was considered that the number of new mutations induced in any individual by radiation was directly proportional to the total dose of radiation that he or she had received. A certain amount of evidence has since been obtained from animal experiments suggesting that, at least as far as the particular mutations studied are concerned, the effect may be substantially reduced if the total dose is received at a low rather than a high dose-rate. As mentioned above, radiation from natural background and fall-out is received at very low dose-rates and it would therefore be reasonable to infer, if further evidence confirms these findings, that any mutations induced by radiation from these sources might prove to be fewer than have hitherto been estimated.

EXISTING AND FORESEEABLE LEVELS OF EXPOSURE TO RADIATION

Medical radiology. In the 1956 report it was recommended that a review of radiological practice should be undertaken to establish the true position in this country, and a committee appointed by the Secretary of State for Scotland and the Minister of Health, under the chairmanship of Lord Adrian, have concluded a nation-wide survey of the hazards to patients from all medical radiological procedures. In their second report, published on December 7, they have calculated that the annual total contribution to the genetically effective dose to the population from all forms of medical radiology was 19·3 mr. This is less than the previous estimate for diagnostic radiology alone, given in the Medical Research Council's 1956 report. However, medical radiology contributes a bigger dose than any other source of man-made radiation and the Adrian Committee consider that the dose could be reduced to 6 mr, without curtailment of essential radiological services, if greater consideration were given to improvements in technique.

Occupational exposure to radiation. The Committee have considered the recommendations of the International Commission on Radiological Protection concerning permissible levels of occupational exposure to ionising radiation and (as mentioned below in the section on the Assessment of Hazards of Exposure to Radiation) they conclude that, in general, these form a satisfactory basis for radiation protection at the present time. They have also reviewed the doses received by workers in the United Kingdom who are exposed to radiation in industrial, medical, and other occupations. They estimate that in spite of the increase in the use of ionising radiations the genetically effective dose as averaged over the whole population from the exposure of such workers is at the present time only about 0·5% of that from natural background radiation.

Fall-out from nuclear weapon explosions. In 1956, little information was available on the amount and distribution of radioactive fall-out from nuclear weapon explosions. However, in recent years there have been extensive observations of radioactivity at various levels in the atmosphere,

in water, food, herbage, and other materials. In particular, the Agricultural Research Council maintains a most comprehensive monitoring programme of the amounts of radioactive materials from fall-out in human diet in the United Kingdom, and this work, together with that of the Atomic Energy Authority, has provided much information on the mechanisms involved in the passage of materials from fall-out into the human body.

From direct measurements it is now known that the "reservoir" of fission product radioactivity in the upper atmosphere or stratosphere is smaller than was estimated earlier—for example, by the United Nations Scientific Committee on the Effects of Atomic Radiation in 1958. It is also known that the rate and nature of the fall-out is influenced by the site and pattern of weapon testing. The radioactive debris released into the stratosphere by explosions in tropical latitudes may take a considerable time, months or perhaps years, before it is transferred to the lower atmosphere and deposited on the ground. Consequently, a large proportion of the original radioactive atoms decay before reaching the earth. On the other hand, radioactive debris injected into the stratosphere in high latitudes, particularly in the autumn, is deposited fairly rapidly; the deposit containing a higher proportion of nucleides which have a short half-life. Although many of the fission product nucleides are taken up into the body sparingly, and thus contribute little to the "internal" radiation dose from fall-out, many of them emit penetrating gamma rays as they decay and temporarily give rise to an increase in the "external" gamma radiation to which the body is exposed.

Strontium 90. The report contains a detailed account of the ways in which the long-lived fission product strontium 90 may be transferred from fall-out through the food chain into human bone. An important finding since 1956 is that the uptake of the isotope by the roots of plants, the magnitude of which is related to the total accumulated fall-out remaining in the soil, is at present of minor significance compared with the direct uptake by the parts of the plant which are above ground. It has also been established that at present the proportion of strontium 90 absorbed by plants in the latter way is dependent on the rate of fall-out rather than on the accumulated total. Consequently, the amount of strontium 90 eventually taken into the body and deposited in bone will be related to the current rate of fall-out, and as environmental contamination with radioactive material diminishes the levels of strontium 90 in bone should gradually decrease.

From the extensive monitoring of foodstuffs carried out by the Agricultural Research Council, it is possible to make estimates of the average concentration of strontium 90 in the national diet. Measurements of the levels of strontium 90 in samples of human bone made jointly by the Medical Research Council and the Atomic Energy Authority have been greatly extended since 1956, and correlation of the results from both dietary and bone surveys have shown that values for strontium 90 to be expected in bone can be derived from the measured levels in the diet.

The average levels of strontium 90 which have been observed both in the diet and in human bone in the United Kingdom are such as to make it extremely unlikely that there has been any appreciable hazard to human health from this isotope.

Caesium 137. Much new information about caesium 137 has also become available since 1956. This isotope has a long half-life of about thirty years but remains in the body for an average time of only about four months, a minority of its atoms decaying during this time and leading to the emission of gamma rays. The estimated gonad dose-rates from caesium 137 are about 1 mr/year in 1958 and 1 to 1½ mr/year in 1959. As the extent to which caesium 137 is taken up by plants and transferred through the food chain into the body is also determined largely by the current rate of fall-out, the dose-rate to the gonads from "internal" caesium 137 will gradually fall as environmental contamination decreases, although "external" irradiation from the accumulated deposit on the ground will continue for some time.

Carbon 14. Most of the carbon 14 produced by nuclear explosions is still in the atmosphere, but it will slowly become more widely dispersed. It has been estimated that the dose of radiation to the gonads from this carbon 14 will be 10 mrems during the generation of thirty years commencing in 1954, and will fall to 5 mrems during the next thirty-year period, the doses in subsequent generations becoming much lower. (These values are to be compared with 3000 mrem received from natural sources during each thirty-year period.)

The total dose, delivered during some hundreds of generations, will be about 120 mrem, which is approximately equal to that received from natural sources during any one year. Some additional genetic effects may result from the "transmutation" of the carbon 14 to nitrogen 14 during its radioactive decay, but these are likely to be fewer in number than those induced by the radiation emitted at the time of the decay.

SUMMARY OF PRESENT AND FORESEEABLE DOSES TO THE GONADS

In estimating the genetic effect of radiation from different sources, the dose accumulated over the thirty-year period of a generation is thought to be the relevant dose to be taken into consideration. The average annual dose-rates corresponding to these thirty-year integrated doses from various sources are summarised in the table opposite.

Possible doses from fall-out under conditions of continued weapon-testing. The Committee emphasise that any attempt to forecast the dose-rates that might have followed the continuation of weapon-testing involves a large amount of conjecture since the levels would depend on many factors, including the amount of testing and the pattern and nature of the explosions.

They have, however, attempted to estimate the dose-rates that would have resulted in this country if nuclear explosions had been continued indefinitely after 1958 so as to produce the same rate of fall-out as the average for the period January 1958 to July 1959. The Committee have estimated that, under such conditions, when equilibrium was reached in about a hundred years' time, the average

gonad dose-rate might be raised to about one-seventh, the dose-rate in new bone to about one-half, and that in bone marrow up to about one-fifth of that received from the natural background radiation. They cannot, however, exclude the possibility that, even for the rate of fall-out assumed, the doses might be several times higher or lower.

ASSESSMENT OF HAZARDS OF EXPOSURE TO RADIATION

Permissible doses of radiation. The Committee feel that it is impossible to state categorically that any dose of radiation will be entirely without consequence and that it is advisable to set levels of radiation which should not be exceeded. These levels must be based on practical considerations which balance the possible risks of harm against the advantages of using radiation in particular circumstances. They have accordingly recommended "maximum permissible levels" of radiation for individuals, for the general population, and for various groups within the population.

The highest maximum permissible levels are for the "occupationally exposed" group, but the Committee stress that just as endeavours are made in any other industry to lower all risks to workers as much as possible, every effort should be made to reduce exposure to the lowest practicable level below that considered permissible. For any fractions of the general population which are not exposed to radiation in the course of their work, but may be brought into closer contact with it than the population in general, the maximum permissible level of exposure is set lower than that for radiation workers, since such populations may include children, whose tissues are more sensitive to some effects of radiation than are those of adults. Moreover, the special medical supervision and personal monitoring procedures applied to those who are occupationally exposed do not apply to members of the general public. The average maximum permissible level for the population of the country as a whole is set even lower since a dose which could be incurred by a small fraction of the population, without harm to its members or appreciable genetic risk to their families, might nevertheless have significant genetic effects if incurred by the population as a whole.

In advising upon the maximum permissible doses which

GONAD DOSE LEVELS

Source of radiation	*Average annual dose-rate (millirads per year)*
National background	Range: 85–106
Medical radiology: 1957 level	19
Miscellaneous sources	Less than 1
Occupational exposure: 1959 level	0·5
Fall-out:	
Maximum value for mean dose-rate in any thirty-year period from nuclear explosions up to November 1958	1·2
(Average value over five-year period 1955–9: 2·4 mr/year)	
(Dose-rate in July 1959: 6 mr/year)	

may be received by these groups, the Committee have, subject to certain qualifications, endorsed the recommendations of the International Commission on Radiological Protection which were adopted by the Commission in September 1958 and extended in 1959.

Permissible levels of strontium 90. In their 1956 report the Committee said that "the maximum allowable concentrations of radio-strontium in the bones of the general population, with its proportion of young children, should not be greater than 100 micro-microcuries of strontium 90 per gramme of calcium". Subsequently, the International Commission on Radiological Protection recommended that for contamination with material such as strontium 90, the radiation from which is confined mainly to one type of tissue, the permissible average level for the general population should not exceed one-thirtieth of that regarded as permissible for individuals who are occupationally exposed to radiation; and that in no individual in the ordinary population should one-tenth of the occupational level be exceeded. The occupational level now recommended by the Commission is equivalent to 2000 micro-microcuries of strontium 90 per gramme of calcium. On this basis, the maximum permissible concentration of strontium 90 in bone averaged over the whole population would be 67 micro-microcuries per gramme of calcium; and the maximum for any individual member of the population would be 200 micro-microcuries per gramme of calcium.

The Committee point out that these recommendations refer to the permissible levels when strontium 90 is the sole source of radiation in bone additional to that received from the natural background and medical radiology, and they accept them in this sense. In 1956, there was great uncertainty about all aspects of the problem presented by strontium 90. In particular, the Committee had little information on the extent to which the concentrations in bone might continue to rise even if nuclear weapon-testing should cease. They therefore made the precautionary recommendation that immediate consideration would be required if the concentration of strontium 90 in human bone showed signs of rising greatly beyond 10 micro-microcuries per gramme of calcium.

With increased knowledge of the factors which determine the levels of strontium 90 in newly formed bone, the Committee do not now envisage, as they did in 1956, that bone concentrations of this isotope would continue to rise considerably after a decrease or cessation of weapon-testing. Nevertheless, since they cannot at present reckon all additional sources which contribute to the irradiation of bone or bone marrow, they still think it wise to adopt a cautious attitude. They recommend, therefore, that if the concentration of strontium 90 in bone, calculated as an average for any age group, including the groups of infants and young children, was found to be rising continuously and to have reached the level of one-half of that recommended as the maximum permissible level for the population as a whole, a reassessment of the situation would be required. The present cautionary level therefore corresponds to an average value of 33 micro-microcuries of strontium 90 per gramme of calcium in human bone at any age.

A NEW LOOK AT SOME SURFACES WITH MULTIPLE-BEAM INTERFEROMETRY

PART II

S. TOLANSKY

This technique for revealing minute changes in surface height can also be used to study vibration patterns and obtain a clear three-dimensional picture of a complex surface. Basic difficulties make it impossible to use this method to study most biological specimens, however.

OSCILLATING QUARTZ CRYSTALS

Quartz crystals play an important part in radio-frequency control and in the accurate measurement of time. They can be induced to oscillate in flexure, extension, shear, and torsion, or a combination of these, and can also be induced to oscillate in a sequence of modes—that is, with successively higher and higher overtones. Since such things as crystal defects, twinning, and deviations from geometrical perfection can produce additional effects, it is obvious that we are faced with a subject of considerable complexity.

Most of the information which has been obtained about oscillating quartz crystals has been electrical. Although it is possible to examine oscillating crystals in polarised light, this technique offers limited information. One can determine the distribution of nodes and antinodes by sprinkling lycopodium powder on the vibrating surface, but the results are crude and, again, only restricted information is obtainable.

Multiple-beam interferometry, on the other hand, offers a beautifully simple way of finding both the distribution of nodes and antinodes, and the actual amplitudes of vibration. The technique is simple. The crystal must first be polished to a degree of smoothness higher than is normally required in an oscillator. It is then silvered and placed on a silvered flat, which acts as one of the electrodes. A wire grid that acts as the second electrode is placed above the crystal.

With the crystal at rest, the fringes produced between the lower surface of the crystal and the flat are a series of straight lines. When the crystal is set into oscillation, however, the fringes broaden out where the amplitudes of oscillation are large and the entire distribution of nodes and antinodes is revealed.

Fig. 17 is an interferogram of an oscillating 1-in. quartz disc with the dispersion deliberately reduced so that 40 fringes covered the field. A striking pattern of circular and radial nodes is revealed that is reminiscent of Chladni sand figures. Maximum amplitudes are of the order of half a light-wave or so, virtually below the limit of resolution of a microscope, even at its best.

The fringe pattern in Fig. 18 has the highest resolution yet obtained with

FIG. 17. Multiple-beam interference pattern obtained with an oscillating quartz disc, 1 in. in diameter.

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FIG. 18. Interferogram of specially prepared quartz crystal, showing highest resolution obtained so far with multiple-beam interferometry. Width of fringe is 15 Å. 800×.

multiple-beam fringes—3 Å, or 3×10^{-8} cm. It was obtained by using a special technique:

A crystal of synthetic quartz was first silvered in the usual way and a dilute solution of Collodion in acetone was then poured on top. As is well known from electron microscope studies, the film which forms when the acetone evaporates closely conforms to the micro-structure of the surface on which it is formed. Here it conformed with the silvered crystal face to within molecular dimensions. Before the film dried off, a somewhat more concentrated solution of Collodion was poured on and drained off. This thicker film dried with a smooth, reasonably flat, upper surface that was then silvered.

Multiple-beam fringes resulted from the interference between the light rays reflected from the contoured lower surface of the Collodion film and those reflected from the smooth upper surface. The system was completely stable and, as the film was thin, the definition was high. With a high lateral magnification, the upper Collodion surface was effectively plane over the small area studied and effectively molecularly smooth in terms of microscope resolution. The magnification in depth was enormous—no less than 1,500,000. The width of the fringe was only 15 Å; if we maintain our criterion of being able to resolve displacements of 1/5th of a fringe width, we have a resolution here of 3 Å—a remarkably small amount. This interferogram is not an isolated freak. We have secured many comparable ones with other crystals.

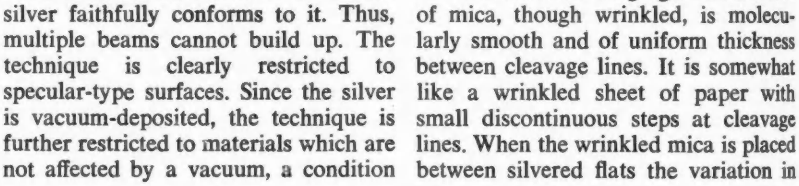
LIMITATIONS WITH BIOLOGICAL SPECIMENS

The multiple-beam interference method is not of very much use in biological studies. When silver is deposited on a matt surface—as are many, if not most, biological surfaces—the surface remains matt because the silver faithfully conforms to it. Thus, multiple beams cannot build up. The technique is clearly restricted to specular-type surfaces. Since the silver is vacuum-deposited, the technique is further restricted to materials which are not affected by a vacuum, a condition usually unlikely in biological materials.

When an attempt was made to study a thin biological cellular specimen by placing it between two silvered flats, we obtained very confused fringes which were quite difficult to understand. Their origin was settled by repeating the experiment with thin sheets of cleaved mica (unsilvered). The fringe patterns produced with a good-quality muscovite mica were quite astonishing; an example is shown in Fig. 19. Each fringe was double, and a sheet of Polaroid showed that the members of the pair were plane-polarised mutually perpendicularly. This occurred merely because of the birefringence of the mica, but the pairs were strange. In some regions they were straight and in others they zigzagged. Even more strange were the pairs in which one component was zigzag and the other was nearly, but not quite, straight. Separate regions were clearly isolated by cleavage steps, running here in the vertical direction.

We established long ago that a sheet of mica, though wrinkled, is molecularly smooth and of uniform thickness between cleavage lines. It is somewhat like a wrinkled sheet of paper with small discontinuous steps at cleavage lines. When the wrinkled mica is placed between silvered flats the variation in

FIG. 19. Multiple-beam fringes obtained with mica. 45×.



the thickness of the air film between the mica and the reference flats produces the interference pattern seen here.

Since such a complex pattern results from a wrinkled sheet of uniform thickness and of uniform refractive index, it is apparent that the situation would be made hopelessly complex if we tried to obtain multiple-beam interferograms of biological specimens which not only have wrinkled surfaces but, in addition, have variations in thickness and refractive index. It can be concluded, therefore, that the method just considered should categorically *not* be used for biological materials, since the resulting fringe pattern would be virtually impossible to interpret. Good interferograms have been secured from polished coal and wood surfaces, but these can hardly be considered typical biological materials. Observations made on such surfaces have merely shown how regions of different hardness have responded differently to polishing, not a particularly useful kind of information.

SUPERPOSED FRINGES GIVE 3-D VIEW OF COMPLEX SURFACES

To get a useful topographical picture of a complex surface with multiple-beam fringes, it may be necessary to obtain a very large number of interferograms, as many as fifty in some cases. This would necessitate a formidable experimental synthesis. The use of "crossed fringes" eliminates all this work and gives a truly vivid three-dimensional topography on a single photograph.

As I pointed out in the first part of this article, a surface that is very nearly parallel to a matching flat will produce an "interference contrast" pattern, the regions of different height appearing with different intensities. These extremely broadened, highly dispersed fringes—this is in effect what they are —show up structure in sharp contrast with high sensitivity but do not easily give good numerical information, for intensity differences are notably difficult to assess. By a process of superposition, however, it is possible to obtain not only a good pictorial representation but accurate numerical data as well. The technique is as follows:

The system is first arranged to produce a broad-fringe interference-contrast pattern and an exposure is made on a photographic plate. Without removing the plate from the camera, the object under study and the reference flat are then adjusted to produce the usual sharp narrow-line fringes and another exposure in made.

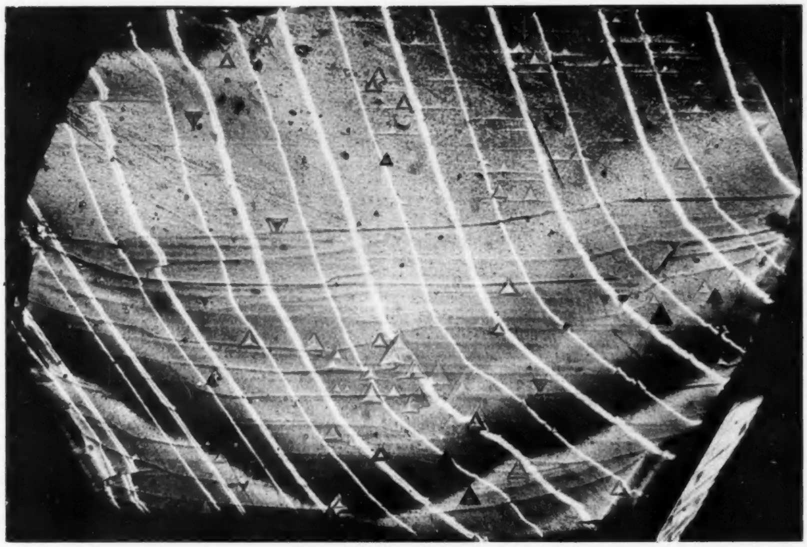


FIG. 20. Superposition of narrow-line fringes on broad-fringe background pattern for three-dimensional picture. 24×.

The use of this technique on the surface of a diamond is shown in Fig. 20. The broad background fringes vividly show up shallow trigons, many of them with linear basal extensions that are doubtless linear dislocations occurring in crystallographic directions which are mutually inclined at an angle of 60°. The sharp fringes (they are actually in sets of three because of the green and two yellow lines in the mercury light source) show kinks and displacements at the dislocation lines.

FIG. 21. Superposition of two sets of narrow-line fringes on broad-fringe background, giving an even clearer three-dimensional view of a surface. 24×.

This is not a very complex case, however; the following example shows what really can be done. As there is no need to stop at a single crossing, one can "double-cross" by placing two sets of sharp fringes at right angles to each other, producing, thereby, a high-sensitivity grid. The use of this technique on the octahedron face of a diamond is illustrated by Fig. 21. The broad patches are, again, the interference-contrast pattern; the two closely spaced lines are the two yellow lines of the mercury light source and the other is the green line. This photograph gives a vivid three-dimensional picture of the entire surface and contains a mass of information, quantitative as well as qualitative. Growth sheets can be seen piled on each other, step-wise, and their curvature recognised, the depths of trigons can be assessed and so on. The information in this one picture is considerable. This technique deserves to be widely used, but it has excited little attention so far, undoubtedly because it is critically difficult to secure really good pictures.

FRINGES OF EQUAL CHROMATIC ORDER

Up to now, the entire discussion has been restricted to one type of fringe system, but several others have been developed in my laboratory and are in active use. A brief description of one of these, in which a spectrograph is used to get fine detail, will be included here.

A parallel beam of white light is sent through the interference system at normal incidence. An image of the surface under examination is then projected with a microscope on to the slit of a spectrograph which selects a narrow-line element. The result is a series of fringes, each at a different wavelength, each having the typical multiple-beam sharpening. Each fringe is a profile line-section of the region selected by the slit. Accuracy, sensitivity, and magnification can all be high. For reasons into which we need not go here, these fringes have been called "fringes of equal chromatic order".

Fig. 22 shows such fringes produced by a piece of mechanically polished glass. Each is the same shape as its neighbour and each is a profile of the surface. Polish marks and a fine-scale waviness can be detected. Fringe width is about 1/50th of the spacing (depending on the wavelength selected) and vertical variations are magnified 400,000 times. This magnification can be increased by using a higher dispersion spectrograph and one has no difficulty in exceeding 1,000,000× if required.

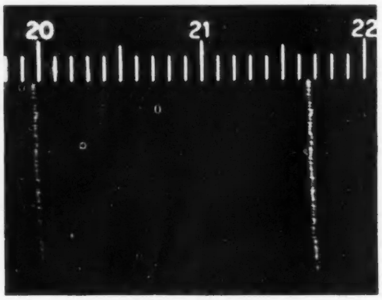


FIG. 22. Fringes of equal chromatic order produced by a piece of mechanically polished glass, showing polish marks and a fine-scale waviness. 30×.

Fringes over a curved hillock are shown in Fig. 23 and fringes over a small depression on a diamond surface are shown in Fig. 24. With a vertical magnification of 500,000, the depression in the diamond is seen to be about 300 Å.

SOME GENERAL CONSIDERATIONS

In all of the work described, constant mention has been made of the glass reference flats. The question of how flat they are should probably be answered here. I have found that the best reference flat is "fire-polished" glass. The selection of pieces which are flat to within half a wavelength over a square inch is relatively easy. If one's attention is directed to a region extending over 0·1 mm. when using a microscope, the glass in the field of view will be flat to within 1/500th of a light-wave.

What is of paramount importance, however, is not flatness but *smoothness*. Locally, fire-polished glass is effectively molecularly smooth. It is as if the initially liquid-glass surface had frozen and retained the smoothness of a highly viscid liquid.

All of the fringe patterns shown here have been obtained with cheap, thin, fire-polished plate glass. In the majority of these pictures, the glass has been silvered, but we have also exploited the use of multi-layer dielectric reflectors.

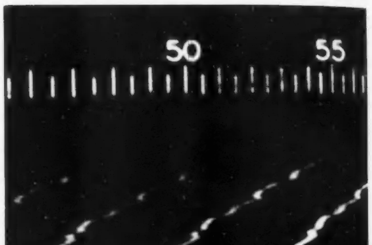
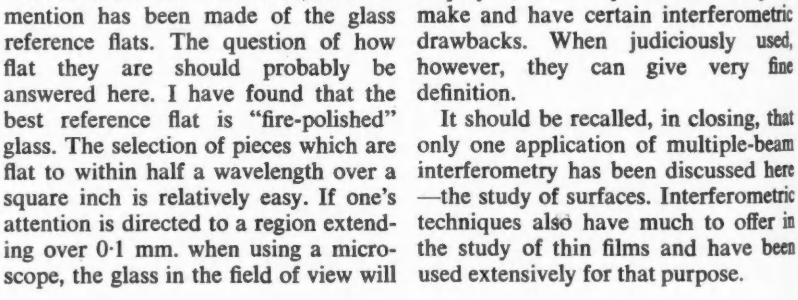


FIG. 23. Fringes of equal chromatic order over a curved surface. 13×.

These have low absorption and give high contrast when reflection fringes are employed, but they are not easy to make and have certain interferometric drawbacks. When judiciously used, however, they can give very fine definition.

It should be recalled, in closing, that only one application of multiple-beam interferometry has been discussed here—the study of surfaces. Interferometric techniques also have much to offer in the study of thin films and have been used extensively for that purpose.

FIG. 24. Fringes of equal chromatic order over a small depression in a diamond surface. 75×.



ASTRONOMY IN THE SOVIET UNION

PATRICK MOORE

A visit to the U.S.S.R. shows that Soviet scientists are giving a great deal of attention to the purely astronomical side of space research. When their giant 236-inch reflector is completed, it is likely to extend our penetration into space well beyond the 5000 million light-years reached with the 200-inch telescope at Mount Palomar, California.

During the last few years, so much has been heard about Russian space research that we sometimes tend to forget the comparable progress there in what may be termed conventional astronomy. During a visit to Soviet observatories in the latter part of 1960, I was able to obtain some first-hand information, upon which this report is based.

It is often suggested that the only purpose behind space research is to send men into orbit round the Earth, or to the Moon, or to one of the near planets in our solar system. This is certainly not the case. At the present stage of development, it is undoubtedly more important to send instruments. Manned interplanetary flight will presumably be achieved in due course, but it is only one of the many aspects of the entire field of investigation. Soviet scientists appreciate this as clearly as their colleagues in the West. The launching of a man into orbit will certainly have immense propaganda value and will probably be given undue emphasis and publicity, but this will be a fault that is by no means confined to the U.S.S.R.; it will be just as marked in the United States.

ATLAS OF MOON'S FAR SIDE

The purely astronomical side of space research is being given a great deal of attention in the Soviet Union at the present time. The analysis of the photographs that were taken of the far side of the Moon with *Lunik III* has now been virtually completed by Y. N. Lipski and his colleagues at the Sternberg Institute in Moscow who worked with research teams from the observatories at Pulkovo and Kharkov. Over thirty photographs were taken, and though only two have been widely published, the others are good enough to yield valuable information. A chart has been drawn up with a catalogue of formations that is divided into three parts. The first includes 252 features which may be reliably identified on at least three of the pictures; of these, about a hundred lie on parts of the Moon which may be seen from the Earth, and the rest are new. Part II of the catalogue contains 190 features that appeared on two *Lunik* photographs. Part III includes 57 features that were identified with less certainty.

The arrangement of the formations on the Moon's far side is of the greatest interest to selenologists since it may yield invaluable information about the origin of the craters. There is no general agreement on this so far, some astronomers believing the craters to be of meteoric origin and others preferring a volcanic theory. I suggested in 1953—basing my argument on the latter hypothesis—that the averted surface of the Moon contained fewer of the dark *maria*, or "seas", than the portion of the surface we have always seen. This has now been confirmed. The numerous craters and other features that have been found on the far side were not surprising; their existence has always been regarded as a near certainty. It is likely that more rocket vehicles of the same sort will be launched before long, providing additional information for more accurate maps of the Moon.

The "probes" sent to the Moon by the Soviet Union have yielded other kinds of useful information, such as the fact that the lunar magnetic field appears too weak to be detected at all. This is purely "astronomical" information that could hardly have been obtained in any other way.

EQUIPMENT AT MAJOR OBSERVATORIES

There have also been major developments in the construction of telescopes and associated instruments. Particularly impressive is the rebirth of Pulkovo Observatory outside Leningrad. Founded by F. G. W. Struve, Pulkovo has always been regarded as the leading Russian astronomical centre. It was too close to the battle-line during the siege of Leningrad in World War II, however, and German shelling reduced the entire establishment to a mass of twisted wreckage. Some of the equipment was saved by being transferred to Leningrad itself, but the Russians were faced with the complete reconstruction after the cease-fire. This has now been achieved, and no trace of war damage remains.

Pulkovo now has twenty-six optical telescopes, including a fine 26-inch Zeiss refractor and over a dozen radio telescopes. As in all great observatories, the main emphasis is on stellar and solar research, and studies of galaxies. It is significant, however, that attention is also being paid to the Moon and planets. A planetary laboratory has been established under the supervision of Dr A. Markov, who is particularly noted for his studies of the Moon. There is a great deal that can be done in a laboratory, apart from visual and spectrographic observations. To give one example, studies can be made of various substances that may be found in planetary surfaces. Soviet experiments have led to the conclusion that the surface of the Moon is composed mainly of slag and give little credence to the "dust-drift" theory proposed by Gold and others.

Astronomical research is primarily based on the practical work carried out with the aid of very large telescopes.

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Up to now, the world's greatest reflectors have been erected in the United States—the 100-inch at Mount Wilson, the 120-inch at Lick and, of course, the 200-inch at Palomar. There has been nothing comparable in Europe, although a 98-inch unit is being prepared for the Royal Greenwich Observatory at Herstmonceux. The climate in England is by no means as favourable as might be wished, however.

The Russians are making great strides in the right direction. They are now perfectly capable of undertaking the entire construction of large reflectors. Much of their equipment is already Soviet-made and of extremely high quality. After looking for a suitable site for their larger telescopes, they selected the Crimea. It would have been pointless to erect a giant reflector at Pulkovo, for the Leningrad climate is frankly poor, from the astronomer's point of view. Conditions near Moscow are not so bad, but are still very mediocre. The Crimea offered better prospects. A 50-inch reflector has been in use for some time at the Crimean Astrophysical Observatory, which is located some distance from the town of Simferopol.* The reflector is a German Zeiss and is used for some lunar and planetary work as well as the astrophysical studies for which it was originally intended. Much of this research has been carried out by Dr N. A. Kozyrev—in fact, it was with this unit that he made his famous observation of a disturbance in the lunar crater Alphonsus on November 3, 1958, proving thereby that the Moon is not as inert as some authorities believed. The exact nature of this disturbance is still uncertain and has caused much controversy, but there is no doubt that a disturbance of some sort took place.

This 50-inch telescope has now been joined by an even larger one—a 102-inch-diameter reflector that is now the largest telescope in Europe and the third largest in the world. Made in the U.S.S.R., it was brought into use last November. Although it will be utilised primarily for research on some of the greater problems of the stellar universe, some attention will also be given to the Moon and planets as well. Very little of the work will be visual. Most of it will be carried out spectrographically and special auxiliary equipment is now being designed.

The Crimean Observatory is widely known for its studies of the Sun; its Director, Dr Severny, is one of the world's leading solar physicists.

PLANS FOR GIANT 236-INCH TELESCOPE

The reports concerning the projected 236-inch Soviet reflector have caused great interest. When ready, this telescope will surpass even the Palomar giant. With its correspondingly better light-grasp, it will be able to extend our investigations farther into space, perhaps well beyond 5000 million light-years, the distance of the most remote galaxy found so far by astronomers in America. The fact that the Russians are able to make a reflector of such size is a tribute to their progress in the construction of scientific instruments. The designs have been approved and considerable progress already made. The completed mirror will apparently weight 40 tons. The total weight of the movable parts of the telescope will be 540 tons, indicating the unit will be lighter and more compact than the Hale reflector. It is not likely that it will have any revolutionary features; none are necessary.

It had originally been suggested that the 236-inch might be set up in the Crimea, but this idea has now been abandoned. A special investigating group that was organised at Pulkovo has sent expeditions to all parts of the Soviet Union in an effort to find the site with the most favourable conditions, as was done in America before Palomar was selected as the best location for the 200-inch. The whole problem has been studied very carefully and no part of the U.S.S.R. has been overlooked as a possibility. There is, of course, a wide choice—not only in European Russia but also in Siberia. There is no major observatory anywhere in Siberia at the present time, although a new one is to be established near Novosibirsk, in the region of Omsk. So far as is known, no definite decision has been made as yet, although it now appears the site will be in Central Asia where conditions are considerably better than in the Crimea. It cannot yet be said when the reflector will be ready. The optical and mechanical problems are immense and cannot be solved quickly. According to one estimate, the telescope will be in use by 1966 or 1967, but this may be over-optimistic. In any case, the work should be completed within the next decade.

The plan to erect a vast telescope of this size underlines the fallacy of supposing that modern Soviet astronomy is concentrated mainly on our near neighbours in space. The general programme there is similar to that of Western countries although the space experiments have drawn worldwide attention to their studies of the Solar System. Theoretical astrophysics in the U.S.S.R. is in a flourishing state and a great deal of important original work is being done.

ASTRONOMY HAS BRIGHT FUTURE IN U.S.S.R.

There are no fears about the future of astronomy in the Soviet Union. Every encouragement is being given to amateurs as well as students; the number of astronomy students that are graduating each year is in the thousands. The success of the planetaria which have been built in various cities is evidence of the general interest and enthusiasm. The one in Moscow, for instance, admits 3000 people every day. Unlike the London Planetarium, it is run as a scientific institute instead of a commercial proposition and can thus be used to proper advantage. No attempts at overdramatisation are made and indeed none are necessary. At suitable times, eminent Soviet astronomers join the regular planetarium staff to give lectures and there are several small observatories on the grounds that enable the beginner to "see for himself". Leningrad has a similar planetarium as well as an amateur-built installation similar to the stardome planetarium in the Science Museum in South Kensington.

A final point which should be made here is that there are no security barriers in "conventional" astronomy in the Soviet Union; information is exchanged freely with the West in this sphere. If more is heard about the space projects, it is only because they make more sensational newspaper stories.

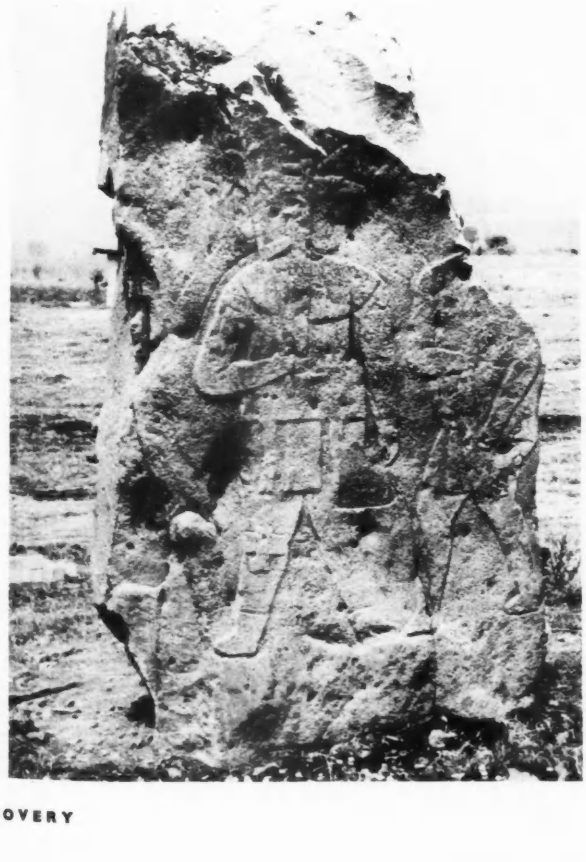
* The domes have been erected on the site of an ancient village which appears to have flourished between 600 and 700 B.C.

ARCHAEOLOGICAL TREASURES OF MEXICO'S GULF ZONE

IRENE NICHOLSON

FIG. 1 (*below*). Preclassic Olmec low-relief found in Veracruz, believed to date back to the last fifteen centuries B.C.

FIG. 2 (*right*). One of the colossal early classic Olmec heads from the 2nd to 5th centuries A.D. Carved in andesite stone, it is over 5 ft. high and weighs 7 tons.



In most of the important archaeological zones of Mexico, many of the important finds are being kept in appropriate surroundings by local museums. This is as it should be, for something subtle and elusive is lost when they are transferred to the more cosmopolitan settings of large cities. The old stones are not of the rolling kind.

The latest of these lovingly tended local museums is in Xalapa, capital of the State of Veracruz. Treasures from the many archaeological sites in the region have been gathered in its own specially designed modern laboratories and exhibition halls. The whole impulse is local, but there is none of the slipshod attitude which tends to be associated with provincialism. The Governor of the State, Señor Antonio Quirasco, has taken a special interest in the building, peasants have donated farm land for the site, and a local archaeologist, Dr Alfonso Medellín Zenil, is in charge.

The variety of styles represented is astonishing. One of the oldest pieces, Fig. 1, is dated by Dr Medellín anywhere between the 15th century B.C. and the first of our era. It is preclassic Olmec low-relief, stylistically not unsimilar to early Egyptian carvings.

Very much more advanced in technique are five colossal early classic Olmec heads from the 2nd to the 5th centuries A.D., one of which is seen in Fig. 2. Carved in andesite stone, they are over 5 ft. high and weigh 7 tons each. The features are negroid, with thick lips and broad noses. A helmet of jaguar skin with well-marked claws just above the eyebrows suggests that these heads were portraits of

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great leaders or warriors—they may all be of the same man. The jaguar was the chief deity of the Olmecs, and no ordinary human being would wear his skin.

From the late classic Olmec period (6th to 9th centuries A.D.) there is a small and very elaborately decorated clay figure, Fig. 3—a round-cheeked little lady with an artificially deformed skull and a faint smile, and the unusual feature of articulated arms. On her ear-rings and gown are the symbols of the rain god and of the sun god and his four movements.

From the same period there are colossal crouching figures, pitted and worn, that seem to be half monkey and half man, Fig. 4, and a magnificently carved basalt mask of the rain god, Fig. 5. Dr. Medellín thinks that the fissures on the cheeks and the prominent teeth represent rain.

A little toy ocelot on wheels, Fig. 6, shows that the ancient Mexicans did in fact know the principle of the wheel, although they do not seem to have used it for utilitarian purposes. The dynamic lively humour of the little baked clay figure with his lolling tongue, curly tail and large alert ears makes him one of the most charming pieces in the museum.

According to the local experts, the most important exhibit in the museum is the andesite stele, Fig. 7, to which

FIG. 3 (*left*). Elaborately decorated clay figure with an artificially deformed skull and articulated arms—from the late classic Olmec period, 6th to 9th centuries A.D.

FIGS. 4 & 5 (*below*). Two colossal figures from the same period. (*Right*) a crouching figure that appears to be half man, half monkey. (*Left*) A carved basalt mask of the rain god.

the Mexican Lázaro Hernández Guillermo guided Franz Blom, Karl Rupert, and Oliver La Farge in the 1920s. A study of this stone has just been completed by a local archaeologist, José Luis Melgarejo Vivanco, who believes that it dates back to 1483 and that it contains a curiously correlated Nahua-Tlaxcala-Maya threefold calendar—a combination of two calendars of the Mexican high plateau with one from the south.

The imposed Aztec culture which dates as late as 1450–1519 A.D. is represented by the so-called "maize stone", Fig. 8, a very elaborately carved low-relief completely different in style from any of the Olmec exhibits. The Aztec rain god, Tláloc, and his wife, goddess of water, face one another, each holding a flowering maize stalk which symbolised fertility. Although the design tends much more towards the hieratic symbolic elaborateness of the high plateau, there is at the same time a free and almost flowing treatment as if, perhaps, local spontaneity and merriment had imposed itself on Aztec severity.

Some of these exhibits (Figs. 1 & 4) have been discovered only this year. The rapidity with which Dr Medellín is unearthing valuable material shows both the enormous richness of the area in archaeological treasures and the enthusiasm and capacity for work of the local team.

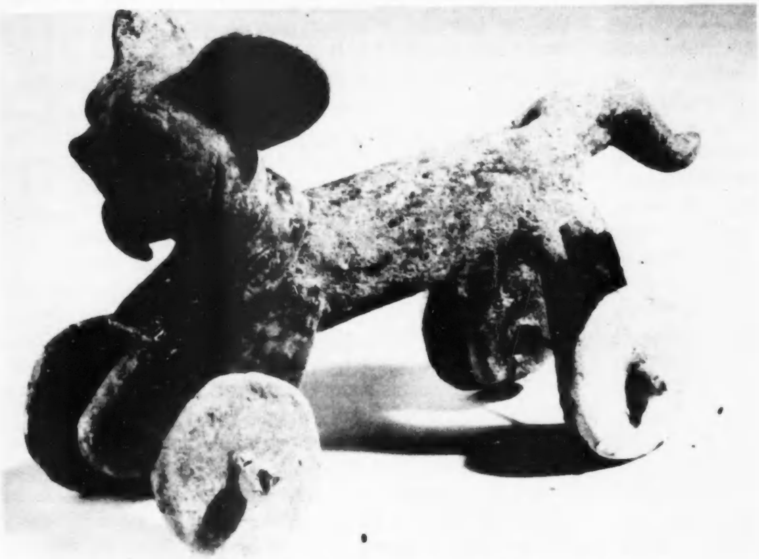


FIG. 6 (*above*). Toy ocelot, baked clay figure from late classic Olmec period.

FIG. 7 (*right*). Andesite stele, believed to date back to 1483, showing a correlated Nahua-Tlaxcala-Maya calendar.

FIG. 8 (*below*). Low-relief "maize stone" from 1450 to 1519 period showing effects of imposed Aztec culture.

THE EMPLOYMENT OUTLOOK FOR SCIENTISTS AND ENGINEERS—SCARCITY OR SURPLUS?

J. F. PETER

Numerous studies have indicated there is a general scarcity and will be for some time to come. This isn ot so, says a staff consultant who contends the "scarcity" is primarily a shortage of "cheaper" manpower in the 20–30 age bracket. Within the next few years, those in the older groups will begin to experience difficulties.

We know by experience that when a young scientist or engineer in his twenties seeks his first or second post, he usually secures several good offers if he is of average quality and his demands—professional, geographical, and financial—are not too high. By the time he is in his thirties, however, opportunities will have shrunk considerably although he should—a little later on—be able to obtain a position as a group or section leader in an ever-expanding industry. He will not have the choice he had previously and he may have to forego his exact choice of field or of geographical location, but opportunities will be available.

Once in the forties, most men will stay with their present companies or organisations. Whether this is by free choice or not is impossible to state, generally, but we know that many try to change their posts without success and finally give up. The fact is they cannot easily find another position suited to their talents and achievements unless they happen to fit into a chance vacancy at a senior level or accept a post the younger men turn down. The very nature of present organisation is such that by the time a scientist or engineer has reached forty, he is highly specialised in his knowledge unless he has had a variety of jobs, but even diversity does not seem to help. Such men are much more difficult to place in suitable posts despite the constant exhortation to technical men to gain a wide and liberal understanding of the sciences or engineering. Employers, consciously or otherwise, tend to look for a man with specific knowledge and/or experience to do a specific job; this is what they wish to buy ready-made.

So much has been written and spoken about the shortage of scientists and engineers, that the idea there is one has at long last become one of the accepted assumptions of public thinking besides providing a non-controversial and possibly flattering subject for College Prize Days and after-dinner speeches. The only dissenting voices will be those of some of the scientists and engineers who are trying to move from one post to another.

An analysis of publicly advertised vacancies together with many discussions on this subject with representatives of various companies shows that the vast majority of these vacancies are directed at men of thirty or under. A recent check showed very clearly that the number of graduates over thirty that were recruited in the last year or two has been very small, and in some firms nil.

There is, for example, a very real shortage of candidates with one to five years of experience for positions as chemists, physicists, metallurgists, and electrical and mechanical engineers. For posts requiring five to ten years of experience, on the other hand, there may occasionally be a shortage although there is generally some choice of candidates for the employer. For posts requiring more experience or ones that are open to older age groups, there is usually a more than adequate supply. It should be kept in mind, of course, that in terms of quality, there is always a shortage of people in the top 10%.

"SHORTAGE" OFTEN AN EXCUSE

The phrase "shortage of scientists and engineers" is now a ready-made expression which comes easily to the tongue and is bound to come up as a subject during a visit to almost any engineering company. Its meaning varies from one situation to another. Some firms experience a shortage because of conditions in the company—physical, psychological, promotional, etc. Others have a shortage because they have been unskilled in the methods of recruitment. The shortage seems to be the most acute in companies that offer the type of work which has little appeal to the graduate. Although a number of them realise this, they rarely examine and adopt alternative incentive measures. These are the firms in which nearly all of the graduates are young and leave after a few years to be replaced by others.

The word "shortage" often means differing things to different people; some companies speak of a shortage when they do not receive a couple of dozen applications for a post. What is the socially desirable level of competition for a post? A question of this kind has many answers but the balance appears to be struck when the employer neither receives so many applications that the choice is made difficult nor so few that he has virtually no choice. This assumes, of course, that the employer is skilled in making the existence of a vacancy adequately known to potential candidates, a condition that is not always fulfilled.

A variable that must be taken into consideration is geography. A post which is relatively easy to fill in the South may present a sizeable recruitment problem for a firm in the North. It is quite normal to find candidates who will accept a post only in the South; those who make a similar stipulation about moving to or remaining in the North are comparatively rare. To cite an interesting example—of the last fifteen control engineer candidates handled by our office, only three would seriously consider a post in the North.

THE PRESENT TREND

How golden is the future for the scientist and engineer, then? Let us first examine what is happening to salaries. The difficulty companies have had in recruiting young graduates has produced a competitive steepening of salary

curves over the 20–30 age bracket. This has also been evident, though less obvious, in the Civil Service. A survey of several large chemical and electrical engineering firms together with some medium-sized miscellaneous engineering companies shows that the salary of the average engineering or science graduate by the time he reaches 40 is now about £1800 a year and still rising. The range for this age group is £1040 to £4000. (The Civil Service probably have higher minima and lower maxima.) What is going to happen to the average 40-year-old during the next twenty years of his working life? If the cost of living continues to rise as it has done over the past few years, he will probably continue to receive a small rise every year which will be valuable for his self-esteem and help him maintain the same standard of living.

However, the shape of the salary curves as well as the prospects of adequate employment depend on the shortages and the adequacies of candidates at given age and experience levels. As a result of the steadily increasing number of science and engineering students, the largest number of graduates are in the youngest age groups, corresponding, incidentally, to the needs of industry. The accelerating output of the Universities and Colleges of Technology means there will be an even greater number in the youngest age groups over the next few years.

The age and salary structure of the scientists and engineers in a fairly typical research laboratory or electronics firm is as follows:

Age	*Ratio to those in 40+ Group*	*Approx. Salary range*
40+	1	£1500–£2000
30–40	2	£1200–£1800
20–30	4	£ 800–£1300

The unsatisfied demand represents an additional 0·6 to 1 in the 20–30 age group.

This age structure does not, on the whole, apply to smaller firms, particularly in the electronics industry where a much commoner ratio is five in the 20–30 group for every one in the 30–40 group. This works quite happily so long as four of the five can, before reaching 30, go on to expanding firms that are seeking men with their experience. It would embarrass the smaller companies if these men stayed, however, since most of their work can be handled by younger graduates with up to five years of experience. It is too much to expect these companies, particularly the smallest ones, to evolve an age structure more expensive than they need to get the work done.

THE YEARS AHEAD

Over the next five years we should see a considerable change in the availability of candidates. The present shortage of candidates in the youngest age group will be eliminated and with the slackening pressure there appears to be every reason for a return to shallower salary curves for this group. In the meantime, many in the present 20–30 age group will have moved into the 30–40 bracket where occupational mobility and staff turnover will have diminished.

The gradual development of job analysis and job evaluation techniques in industry will eventually force firms to face this situation with a policy. The increasing supply of new graduates is solving our immediate and urgent problem of recruitment but it may at the same time be producing new problems of another kind. What will happen to the scientists and engineers in the older age groups? It may be argued that there will be a hiving off of some to give a welcome strengthening to management and administration but a move in this direction may be countered by the argument that a good many firms have been weakened rather than strengthened by the appointment of technical men to administrative positions who, for one reason or another, good or bad, happened to be available for transfer. Moves of this kind sometimes turn out to be fortunate but they can also prove disastrous. The difficulties may result from the fact that engineering industries, on the whole, do not utilise modern management practices that accent training and evaluation techniques; they tend to lag behind other sectors of industry and commerce in this respect. The winds of change are blowing, however, and management development schemes are beginning to find acceptance in the engineering world with the consequent discovery and training of new management talent from the middle age range of technical and scientific staffs.

A surplus of scientists and engineers in the 30-plus group may have far-reaching effects on our society. Once the present disparity in salaries between technical and non-technical jobs has been reduced, we may see more scientifically trained people in teaching, journalism, public relations, personnel work, advertising, and commerce—fields which are largely staffed today by those who have studied other disciplines. An education in science or engineering will perhaps no longer be regarded only as training for a specific kind of job but also as a general education.

The price we are paying for the present shortage is the channelling of nearly all of our scientists and engineers into highly technical careers, thereby isolating them from their fellows. An increase in competition in the middle and older ranges may result in a greater spread of scientists and technologists through our society and do something towards bringing about a greater mass acceptance of scientific ideas and the scientific approach.

Already two-thirds of the Sixth Formers in the Grammar Schools are science students and a growing proportion of these are entering universities or colleges of advanced technology. It would be valuable to know how much of this mounting influx is due to exhortation in public places, changes in fashion and public interest, and/or an eye towards a lucrative career. It would be too much to assume that a dedication to scientific ideas is motivating more than a small proportion. The rising prestige of science and technology may have as much influence as deliberate Government action. Whatever the ultimate changes in public policy on this issue, there is going to be a steadily increasing number of scientists and engineers every year for some time to come. We shall beat the shortage we hear so much about but which is, we believe, a shortage only of "cheaper" graduates to carry out the many and relatively simple jobs in industry. The increase in the 30–40s and the over-40s is going to call for adjustments and new ideas on the part of both the employers and the employed.

POWER FOR INDUSTRY

RITCHIE CALDER

Predicting the future is a difficult and hazardous occupation but it must be done in a modern society nevertheless. One illustration is the necessity of predicting a nation's power requirements far enough in advance to carry out the research, development and construction in time to meet the demand. This is the fifth article in a series on the role of science in industry.

A quarter of a century ago, Lord Rutherford argued the need for a "Board of Scientific Prevision". Its function would be the continuous review of the changes latent in new scientific advances so that men of affairs could make the proper industrial and social judgments and arguments. Some may say—as others did then—that the predictions of the scientific soothsayers would be as fallible as the "hunches" of the businessmen themselves,

We know by hindsight that Lord Rutherford himself, this apostle of foresight, was wrong about the industrial possibilities of his own subject, maintaining until his death in 1937 that the atom would "always be a sink of energy and never a reservoir". And many eminent scientists who were aware of the discoveries then being made in the laboratories agreed with him. Such examples are plentiful.

However, if the now almost forgotten joint committee established by the British Association and Trades Union Congress in 1937 had fulfilled its intention of giving the industrial workers some prevision of the scientific changes which were likely to affect their jobs and their trade union structure, the workers and trade unions would not be as uneasy as they are today about automation and innovations. The future of electronics was fairly plain then, as were the potentialities of man-made fibres and plastics. The committee died unnoticed at the outbreak of the war and has never been reconstituted. The management side of industry might also have benefited from a similar joint committee. The British Association at that time, however, was looking at the section in its charter which called for the "removal of obstacles which stand in the way of the advancement of science" and regarded innate *Luddism** as serious an obstacle as the social hardships of unforeseen change.

In the United States at about this time, the National Planning Board set up by President Roosevelt was enlisting the help of scientists, industrialists, and economists in an effort to arrive at some basis of prediction of technological trends. What is now obvious when we look back at this and other attempts and indeed at the present situation is the difficulty of predicting the speed of change, especially the breakthroughs which release the log-jams and set off whole trains of new events. A classical example, of course, was the discovery of uranium fission which Lord Rutherford could not foresee.

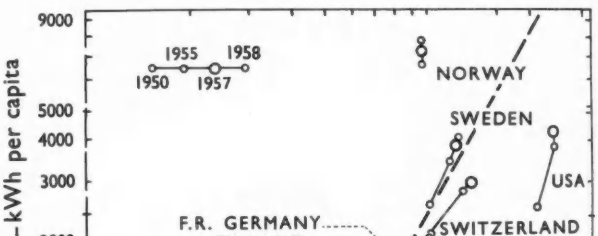
* Said, without confirmation, to be from Ned Lud, a lunatic living in the late 1700s, who, in a fit of rage, smashed two frames belonging to a Leicestershire "stockinger". The term *Luddites* was applied to members of an organised band of mechanics and their friends who went about destroying machinery in the Midlands and the North of England during the period 1811 to 1816.

THE PREDICTION OF POWER NEEDS

There is one sphere of technology in which prediction is not only desirable but imperative—power generation. It is often said that the *per capita* energy consumption of a country is a more realistic unit of comparative prosperity than the *per capita* income but there is an uncanny relationship between the two as is apparent from the latest UN data of Fig. 1. Fig. 2 shows how electric power consumption has been doubling every ten years.

Although the future ability of a country to advance technologically and adapt itself to scientific discoveries depends on the availability of power, the providing of this

FIG. 1. Relationship between electric power consumption and gross national product on a *per capita* basis.



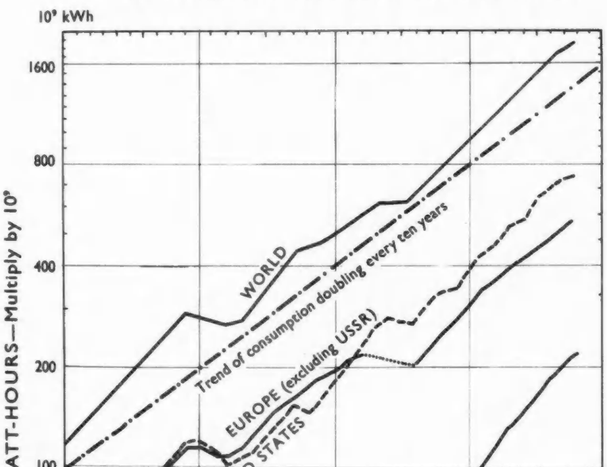
power involves vast sums. In Britain, the Central Electricity Generating Board spends £200 million a year on construction work.

"Power for Industry" involves more than the scientific and technological research which ultimately becomes embodied in generating stations. Meeting future demands necessitates predictions on the most realistic basis because of the large financial considerations. The senior "soothsayer" today is Sir Christopher Hinton, F.R.S., who is now chairman of the Central Electricity Generating Board after being in charge of the atomic energy industrial programme. He is in the exceptional role of being the arbiter between nuclear power, which he so effectively pioneered, and conventional power, in which he "grew up". No one could be better qualified to handle the present and future problems of the three-fuel economy (coal, oil, and nuclear energy) which has replaced the one-fuel economy that has governed the British power industry since the time of James Watt.

"Predicted power plant needs", Sir Christopher explains, "are based on what the maximum demand is going to be. It is this, not the possible number of consumption units, which determines station planning and construction; it is on this that present capital is invested in the future. Construction planning is for five years in advance and only when the forecast year is at hand will

FIG. 2. Trends in electric power consumption showing doubling every ten years.

From "The Electric Power Situation in Europe in 1958/1959 and Its Future Prospects" *by the European Office of the United Nations*



considerations of number of units likely to be sold enter into calculations.

"It is fortunate that 'maximum demand' is now the accepted criterion for planning because 'maximum demand' is more easy to forecast than trends in 'unit demand'. The reason is obvious: Supposing, within the period for which the forecast is made, there should be a recession in industry and firms should have to go on a four-day week, the 'maximum demand' is the same for four days as it is for five or even seven. The generating plant has to have the capacity to 'take the load' when required.

" 'Maximum demand' is singularly insensitive to trade fluctuations. If a whole industry were to close down, the sales of units would suffer, but the stations would have to be capable of meeting the demand the moment it restarted.

" 'Unit demand' is more sensitive but less so than in other basic commodities. Domestic sales, within narrow margins, are predictable. For instance, in hard times, or in a mild winter, the housewife is more likely to switch on the electric fire than to order another ton of coal.

"This principle of forecasting has only recently been fully accepted. In all industry, it was the recognised thing that forecasting should be done on the basis of what the sales people expected to sell. Looking at their possible markets, they would say: 'We have electrified so many homes, farms, and factories. We have provided all the street lighting. We have taken into account the advent of this new housing estate or that new factory. We can expect to sell so many units.' This was equally true in the heavy electrical manufacturing industries, where the sales people would foresee fluctuations in the demand for equipment. Yet the growth of the electrical industry from the 1870s onwards plotted on the chart made a consistently smooth curve.

"The trend of 'maximum demand' is reliable enough for us to say that unless there is some spectacular change —say that our winters suddenly became tropical—the rate of increase is predictably constant. Of course, many observations have to be taken into account in forecasting. It is not enough to rely on the mean weather conditions. It is necessary to have plant available to meet the peak-load of an exceptionally severe winter. Apart from the amount of new plant for the installation of which sanction will have to be sought to cover the period of the forecast (not only expansion but taking into account the factor of obsolescence) there is also the question of location.

"Power estimates give an indication of the parts of the country where plant should be installed. Here it is necessary to remember that 40% of the demand is south of the line from Bristol to the Wash, whereas the bulk of the coal we need is north of that line. This raises the question of the fuel to be employed.

"When the only fuel was coal, planning had become highly proficient even in long-term forecasting. Today it is much more difficult; we are operating within a 'Three-Fuel Economy'. We have to take into account the relative values of coal, oil, and nuclear energy."

THE THREE-FUEL ECONOMY

This three-fuel economy to which Sir Christopher Hinton referred is complicated by factors other than costs. The grim winter of 1947 showed Britain what coal shortages could mean, and the electricity authorities were under pressure to see that it did not happen again. Oil-fired stations were ordered to reinforce the conventional coal-fired stations. Then the Suez crisis came along and made it plain what oil shortages might mean and how the British people might become hostages in an international political struggle. In addition, the experts foresaw a permanent gap between what the British coal-mines could produce and the estimated requirements of expanding British industries in the 1960s.

As a result of all these factors, a programme to generate electricity from the atom was launched as a national emergency measure. Although the cost per unit was expected to be fractionally higher than the cost of electrical power from conventional fuels, the difference was justified on the grounds of the nation's needs. In 1957, in a lecture to the Royal Swedish Academy, Sir Christopher Hinton made the prediction that the cost of fission-produced electricity would drop to that of coal-produced electricity by about 1964. His forecast for the price of nuclear power still holds good, but the cost of coal-produced power has gone down in the meantime because of the drop in coal prices and the increased efficiency of conventional power stations.

> "I was wrong," says Sir Christopher Hinton now, "much more because of the changes in the conventional field than in the nuclear field. I used forecasts which took into account the technical progress which would be made in conventional stations projected at that time and the then rising trends in the price of coal. Both, in the light of subsequent development, were pessimistic. The cost of power generated in the best conventional power stations which are being built has fallen from 0·6*d.* per unit to about 0·52*d.* per unit, and the capital cost per kilowatt of installed capacity has been brought down from £60 per kilowatt to £42 per kilowatt—in spite of inflation. The rise which I anticipated in the cost of coal has been held partly by oil competition and partly by the prospect of nuclear competition. There has been, in the last two years, a halt in the rise of coal costs so that now we buy our coal more cheaply than we were getting it delivered a year ago. With these changes in the conventional field, we now calculate the 'break even' date (when the cost of a unit of power from the nucleus will be equal to that from coal) as between 1966 and 1970."

With unforeseen surpluses of coal piled up and the closing of mines, it might be worth recalling what is involved in the British atomic power programme. The 1955 White Paper envisaged the construction by 1965 of nuclear-power plants with a total electrical capacity of between 1500 and 2000 MW; the subject was to save 5 million tons of coal a year. These plants were to have natural uranium reactors of the Calder Hall type.

During the summer of 1956, there were second thoughts which led to a big expansion of the programme. One of the factors was the discovery that larger reactors were more practical, a result of the work of the consortia—the four combines of engineering companies which were tendering for the stations to be built by the then Central Electric Authority. When they submitted their quotations it was found that with engineering improvements the capacity of a two-reactor station could be twice what had been anticipated. This led to the expanding of the programme to three times its original output target for 1965 and meant an anticipated saving of 15 million tons of coal per year. The prospects of cheap coal or coal surpluses will not affect the fact that by 1970, according to the latest predictions, nuclear power will pass the "break-even" point and should begin to replace coal for "base-load" stations. (Base-load stations are those which run for twenty-four hours a day, supplying the minimum or base power demand, as opposed to "auxiliary" stations which are brought on the line to take care of the additional or peak-loads.)

PLANNING FOR THE FUTURE

In planning with a three-fuel economy, it has to be remembered that 40% of the demand for electricity is south of the line from Bristol to the Wash. The cheapest and most suitable coal for electric power generation is in the East Midlands, South Yorkshire, and the North-east Coast. To take advantage of the cheap coal of the East Midlands, the newest and most highly efficient stations are being constructed on the Trent. But this means long transmission-lines are required to supply power to the South, and this, in turn, brings the cost back up.

The nuclear power stations are, consequently, being located outside the cheap coal regions. This raises some other problems, however, since these stations need to have a certain degree of remoteness to reassure the public, have to be in reasonable proximity to the centres of demand, and need abundant water supplies. If a site is at a convenient distance for power transmission, it is usually one of those "unspoilt" places to which the urban population is likely to go for outings. In planning, therefore, account has to be taken of genuine amenities and of the delays in persuading public opinion that the siting is justified.

The third fuel in the three-fuel economy—oil—does not introduce any serious problems at present as it looks like it will play only a minor role in electric power generation in Britain. This does not mean there is no future for oil, however, for it will be needed for industrial uses—furnaces, heating plants, and the like.

Long-term planning has now become imperative because the three-fuel economy has introduced a great many new variables into the traditional experience of the single-fuel economy that extended back over a period of 150 years. The future of electricity cannot be considered apart from the future of coal—Britain's only great national asset—nor of nuclear energy, in which Britain took such an enterprising lead.

The prediction of future power requirements must be done accurately if an abundant supply of cheap electricity is to be ready when needed to help Britain maintain its place as a leading industrial nation.

THE BOOKSHELF

Translation from Russian for Scientists

By C. R. Buxton, M.A., and H. Sheldon Jackson, M.A. (*London and Glasgow, Blackie & Son Ltd, 1960, xix+299 pp., 30s.*)

Manchester College of Science and technology has distinguished itself by a serious approach to the teaching of languages—especially Russian—to their scientists; it is probably the only college of advanced technology in this country which has established a Department of Modern Languages with a strong Russian section. Two lecturers of that Department are responsible for this Russian textbook.

It is unfortunately impossible to state that this is the textbook that has long been awaited by all those concerned with the teaching of Russian to scientists. Except for a few American publications, there has been little worth while available in this country so far. It is to be hoped, however, that the new book will give some valuable help in this emergency and possibly inspire other authors to produce more Russian textbooks for scientists, as they are so urgently required. Perhaps its best and real value lies in the fact that it can serve as a valuable guide to future authors, who will see from this book what should be followed as a good example and which mistakes to avoid. The most important weakness in this otherwise good book is the fact that there are no accents. Even the grammar and comments are not stressed. This is a serious handicap and will discourage many teachers and students from choosing this textbook, for this is an essential requirement for students of Russian. A beginner in Russian working independently will be quite lost, and those who have the guidance of a teacher will have to be continually led by the hand. They can never be left to work with the book alone. This is almost tragic, and no technical printing difficulty justifies such a decision.

The book consists of 299 pages (including vocabulary), and is divided into five sections: A–E. Section A: Grammar is obviously the most important part and is very well worked out. It not only contains a great deal of information but also gives many valuable and useful rudiments of grammar. This section can serve very well as a reference for a long time, even for more advanced students. It is concise and yet extensive, although it is regrettable that the material, which has been compiled and presented in a masterly way, is not always followed up by comprehensive examples—a highly important need.

While the comparison of Russian with other Slavonic languages seems too ambitious for a scientist learning Russian, the comparison with English, Latin, French and German is very good. However, the explanation of the pronunciation of the sounds *shch* and *ch* as well as *evo* and *ovo*, if not actually faulty, is not clear. Words for reading practice are very well selected and have a scientific bias.

The sentences for translation in Section B are very well selected and most useful. The annotated texts in Section C have also been chosen skilfully, and the section includes very good comments and references. This is definitely one of the best sections of the book.

Section D: Physics and Electrical Engineering and Section E: Chemistry and Chemical Engineering take up as much as 110 pages—that is, more than one-third of the book. Copied from various Russian books and journals (not quoted but generally covered by authors' acknowledgments), they are skilfully selected, but as the texts are not accented or commented, their presence in the book in such disproportion is rather surprising.

It would have been much more valuable if some of these texts had been used to support the grammar section A or enlarge the very good section B (only 23 pages) and section C (only 24 pages).

The book is provided with the necessary vocabulary and includes a rather useful and well-selected list of abbreviations. Text, print, titles, and so forth, are to the highest credit of the publishers, although the book contains a reasonably small number of printing errors which have escaped the correctors.

For those who are not deterred by the lack of accents, this is surely a very good book for the reasonable price of 30*s*.

A. BLUM

Russian for Scientists

By Dennis Ward, M.A. (*London, University of London Press Ltd, 1960, 204 pp., 15s.*)

Dennis Ward—the author of a textbook for the second-year Russian course now run by the BBC for the general public under the title "Keep up your Russian"—has produced a relatively small but remarkable book of 204 pages. It is intended to be used either with or without the assistance of a teacher and was designed to help scientists read technical and scientific Russian literature within the limited field of their own special study

and possibly one or two adjacent fields. The size and scope of this book is limited and the students' work is considerably restricted. It is divided into twenty chapters, covering elementary grammar, including explanations, exercises, and vocabulary, with the material skilfully orientated towards the principal fields of science. The grammar is concise and yet adequate for the purpose.

One of the main features in the approach to the Russian grammar is the fact that the author uses the term "absolutely minimal grammatical marker" instead of the usual term "grammatical ending"—a highly disputable point, especially in the declension of nouns and adjectives and in the conjugation of verbs. Although the author's intention is simplification of work, the result is rather doubtful, as the author himself recognises that the grammatical elements to be committed to memory can often be reduced in size, as it were, though they are not reduced in number; in fact, the orthodox method seems definitely to be more advantageous and correct.

The "one-way" exercises in Russian-English translation are very good, but only two chapters contain short and very good continuous texts. A greater number of similar texts in other chapters would greatly have enriched the book. At the end of the book are four excellent appendices which will be of assistance to students, and a very good vocabulary. In most cases two aspects of the verb are given and, whenever there might be any doubt, the gender of nouns and cases used after verbs.

For a limited purpose, this book could well be used as it is, or in conjunction with other textbooks or technical magazines. A. BLUM

Wave Mechanics and Valency

By J. W. Linnett, F.R.S. (*Published by Methuen & Co. Ltd, 184 pp., 18s.*)

Chemical quantum mechanics is generally regarded as a difficult subject. This is owing to the complicated mathematical concepts which are necessary for the quantitative theoretical description of even simple chemical systems. If a serious student attempted to attend all the mathematics courses necessary to cover the required techniques he would also accumulate most of the knowledge of a mathematics degree as well as that of some post-graduate topics. On the other hand, only a small but particular selection from these is necessary to understand the fundamental theory of the structure of all molecules. But this minimum basic knowledge is not generally found close together and a student has great difficulty in avoiding unessentials in his first study of the subject.

The present book is one of the most successful attempts to help the beginner in these matters. The mathematical treatment is kept briefly to the matter in hand. We reach Schrödinger's general equation for many electrons by page 5; we have defined and used the properties of orthogonal functions and normalisation by page 10. This is done in a clear way with the minimum of mathematical symbols and a general endeavour to use these in the way in which they are practically important for the later description of wave functions of atoms and molecules.

The author's style is of the type which must be good because one does not notice it. One feels he is trying to provide a trustworthy but minimum basis with which one can understand theoretically the behaviour of atoms and molecules. He is, of course, a well-known authority on the spectra and structure of molecules and is, in fact, providing the briefest basis for a reliable understanding of the fields in which he is interested. The main achievement of this book is that it will enable some of those who might get tired or dismayed by a more packed book to find their way through to the theoretical explanations of important branches of structural chemistry.

The first two-thirds of the book treat in this manner the standard simpler problems of chemical structure, the hydrogen atom, the helium atom and the hydrogen molecule and make a good introduction to the abstract types of mathematical functions with which it is necessary to calculate. The last third of the book has necessarily to forsake the simpler deductive treatment of the earlier part. Here a key selection of interesting methods and results of modern theoretical research are described—the essential theoretical ideas of valency hybridised orbitals, molecular orbitals, ligand orbitals of complex ions, etc. These are treated more in the manner of a review; although other specialists might disagree with incidentals, the author's views would be generally accepted.

If this book could be placed on the shelves of every sixth form science library, we should find the scholarship students of the next generation coming to university with a clearer idea of the quantum theory of atoms and molecules than many of their predecessors have obtained after a year or two here. S. F. BOYS

University Chemical Laboratory, Cambridge

Aerodynamic Capture of Particles

Edited by E. G. Richardson (*Pergamon Press, 1960, viii+200 pp., 50s.*)

Some time in 1960 (date not quoted) a Conference was held at the British Coal Utilisation Research Laboratories at which some fifteen papers were presented concerned with basic and industrial problems involving the behaviour of particles moving in a medium of gas or liquid in which there may be solid bodies present. In this book these papers are collected together with summaries of the discussions which followed the three sessions into which the papers were grouped.

The first session was concerned with theoretical and fundamental aspects and began with a useful introductory survey by Prof. Richardson. It was followed by a paper on dust deposition from a turbulent airstream by Prof. Owen, inspired by, and very relevant to, the problem of the deposition of coal dust on the walls of a mine shaft but with wider implications. In the next paper, H. Herne reviewed current literature on the capture of a small particle by a large spherical particle for various flow conditions and anticipated the increasing use of digital computers for more complex problems of practical interest. In the paper that followed, D. J. Brown compared some theoretical and experimental results of particle trajectories, collision with and attachment to air bubbles in a froth flotation process. In the last paper of this session, T. Gillespie reviewed the effects of electric charges that can develop on particles in an aerosol on their rate of coagulation, the efficiency of filters and the deposition on surfaces.

The second session dealt with experimental applications and techniques and began with a paper by A. C. Chamberlain giving the results of some interesting and detailed studies made at Harwell on the deposition of radioactive aerosols from the air to the ground. The smoking of fish inspired the next paper by W. W. Foster on the size and distribution of smoke particles generated when wood is heated in air. In contrast the next two papers by D. C. Jenkins and J. D. Booker and by D. L. Marthew were concerned with aeronautical problems—the impingement of water drops on a surface moving at high speeds (as when raindrops hit a high speed aircraft) and the distribution of particles impacting on the blades of a turbine cascade. The last paper of this session by R. G. Daman presented an interesting review and discussion of the process of filtration of airborne particles.

The final session was concerned with the capture of particles by raindrops. It began with a most interesting account by W. W. Walton and W. Woolcock of an investigation of the collection and removal of airborne dust by water spray in which the practical necessity for high pressure sprays for the removal of the small scale dust met in mine shafts was emphasised. The next paper by L. Hocking was concerned with the theoretical collision efficiency of two small spheres, taking account of the interaction of the two flow fields; the subsequent paper by A. C. Picknett presented for comparison the results of an experimental investigation of the collection efficiency of water drops in air. In the next paper by C. S. Pemberton, a theory for the effectiveness of rain in washing out a suspension in air of non-wettable particles was discussed and it was shown that the effectiveness was considerably less than with wettable particles; the final paper by B. Oakes described an experimental investigation of this topic which showed some qualitative agreement with the theory but also indicated the complex nature of the problem.

The extremely varied nature of the numerous scientific and industrial applications relevant to a symposium of this kind will be apparent from the above summary, and many of them have arisen only in

recent years. It is clear from the reported discussions as well as the papers themselves that on many fundamental points current ideas are still very tentative and controversial and rapid theoretical and experimental developments can be expected in the future which will justify further conferences. These Proceedings should, however, prove a valuable addition for some time to come to the libraries of those many industrial and research institutions that are concerned with various aspects of the subject.

The presentation, printing and paper of the book are excellent and very much better than is usual with current British textbooks; this is presumably a reason for the relatively high price of the book.

A. D. YOUNG

Professor of Aeronautical Engineering, Queen Mary College, London University

The Cell Nucleus

Edited by J. S. Mitchell (*Butterworths, London, 1960, xiii+269 pp., 50s.*)

This volume reproduces the papers read and the discussion which took place at an informal meeting of the Faraday Society in Cambridge during the late summer of 1959. It is not, as its title may erroneously suggest, a treatise on the cell nucleus but is rather to be classed as a symposium. As such, and in common with other symposia, the various papers deal mainly with the current research of the individuals who received and accepted invitations to attend the meeting and are not necessarily representative of the work on the cell nucleus which is in progress throughout the world. The field covered is rather restricted, in fact, for it is largely confined to the biosynthesis and functions of the nucleic acids, the mechanism of their synthesis and its inhibition by irradiation being particularly prominent subjects. Nevertheless, there are also papers on other subjects such as the fine structure of the nucleolus and chromosomes and nuclear enzymes. The proteins of the nucleus are sadly neglected, apart from references to nucleoproteins, despite the fact that they represent some 60% of the dry mass of animal somatic cell nuclei.

It is not possible to deal here with the individual papers nor, indeed, is it desirable, for many of them are largely resumés of work already published. But some comments may be made on a few rather arbitrarily selected topics.

Contrary to the belief of many but not all cytologists who hold that the chromosomes are formed from and contain the whole of the material of the prophase nucleus, one of the contributors (Richards) calculates from his experiments that less than 50% of the dry mass of the prophase nucleus contributes to the formation of the chromosomes. The explanation of this finding, given in the discussion by Gaulden and pointed out by the reviewer some twelve years ago, is that the nucleus contains, in addition to the chromosomes, the material which gives rise to the mitotic spindle. According to Richards, the non-chromosomal material must be protein for "all the D.N.A. is contained in the chromosomes". This, of course, is the orthodox view but there is considerable evidence, as I have pointed out elsewhere, that while the mitotic spindle does contain protein it must also contain D.N.A.

It has for long been generally accepted that the nucleolus contains no deoxyribonucleic acid (D.N.A.), its basophily being attributed to ribonucleic acid (R.N.A.). Nevertheless, there have recently been suggestions that some D.N.A. is also present. In a paper on the Ultrastructure of the Mammalian Nucleolus, Davis now shows that "there is a considerable amount of D.N.A. in the nucleoli" of regenerating liver cells in the rat.

The possibility, occasionally suggested in the past, that D.N.A. arises directly

from R.N.A. has usually been rejected largely because of their difference in base content. Richards now summarises experiments which go far to show that the deoxyribonucleotides necessary for the synthesis of D.N.A. by the Kornberg reactions arise by reduction and other appropriate modification of the ribonucleotides. Apart from its intrinsic interest, this result indicates that caution must be exercised in the interpretation of tracer experiments, for a labelled precursor of R.N.A. may well be incorporated into D.N.A.

The chemical nature of the chromonema—the threadlike early prophase chromosome—has come into dispute. According to the old view, for which there was much experimental support, this structure which carries the genes at fixed loci along its length is composed of protein (chromosomin according to my nomenclature) and is converted into the metaphase chromosome by a process of spiralisation with, possibly, the accretion of other material such as nucleic acid. Callen (quoted by Kaufmann) now believes on the basis of experiments with the rather abnormal lamp-brush chromosomes that nucleic acid is solely responsible for the continuity of the chromosomes. On the other hand, Kaufmann's experiments lead him to conclude that no single substance, nucleic acid or protein, constitutes the essential material, while Schwartz in a speculative paper suggests that D.N.A. and protein alternate in the chromosome. E. STEDMAN

Department of Biochemistry, Edinburgh University

Cellular Aspects of Immunity, A Ciba Foundation Symposium

Edited by Dr G. E. W. Wolstenholme (*London, J. & A. Churchill Ltd, 1960, xii+495 pp., 60s.*)

To commemorate the 10th anniversary of the Ciba Foundation for the Promotion of International Co-operation in Medical and Chemical Research, three conferences were arranged away from its premises in London. The second of these conferences, held on June 3–5, 1959, in the Abbey of Royaumont near Paris, discussed the "Cellular Aspects of Immunity" and this book contains a verbatim and illustrated account both of the papers presented and the discussion.

The thirty-four participants included almost all the leading investigators in this field in Europe and the U.S.A. with the addition of that outstanding Australian immunologist, Sir MacFarlane Burnet. The proceedings consisted of nineteen papers, a panel discussion on the clonal selection theory of antibody formation and a concluding group discussion as a summary.

The widely held hypothesis that several diseases of obscure aetiology are the result of an auto-immune reaction against endogenous antigens has brought to the fore the fundamental problem of the mechanism by which the antibody-forming cells normally differentiate between "self" and "non self". Clarification of this problem must no doubt await a clearer understanding of the normal physiology of antibody production and especially the answer to the question whether the formation of a specific antibody is due to selection of cells already endowed genetically with the capacity to form such antibody or whether this capacity is impressed upon a previously neutral cell by the action of the appropriate antigen. These fundamental questions form the main theme of the symposium and the cellular aspects of immunity are considered mainly in respect of the light that they throw on these two major problems.

It is impossible to do justice to this book in a brief review. It can, however, be said that the intellectual fare provided is no less than would be expected from so distinguished a gathering. One cannot but envy those fortunate enough to have been present but it is no mean consolation that the mental atmosphere of the symposium can be so readily recaptured for the modest expenditure of 60*s*. L. E. GLYNN

Medical Research Council, Rheumatism Research Unit, Taplow

Kina, A History of the Russian and Soviet Film

By Jay Leyda (*London, Allen & Unwin, 1960, xvi+491 pp., illustrated, 42s.*)

Apart from the British documentary tradition started back in the 'twenties by men like Tallents, Grierson, and their younger followers, we have to look to the Russian film for a full exploitation of the medium in the service of society, the impressive and sweeping forces it brings to bear upon the public. This will be a feature of the film in the cinema, never to be paralleled by the television film experience, fragmented as it is and taken out of its elementary social context in the mass cinema.

All of us who are interested and fascinated by this eternal wonder, the film, have been waiting for the first authentic survey and historical discussion of the Russian film, and now we have been given it at long last. The richness of offerings is so wisely and "strategically" spread that the reviewer finds it invidious to single out any part for special praise. This is all on the highest level of historical documentation, commentary, and, despite the deep enthusiasm of the author, remarkably detached writing. The postscript on 1948–58 alone is a masterpiece of concentrated summing-up. The appendices, including a record of a conversation with Tolstoy on his eightieth birthday, and an article by Mayakovsky on Theatre, Cinema, Futurism, both excellently translated, are worth the whole book to any philosopher of the cinema. The publishers, in the very front rank of British producers of books with contemporary thoughts and problems, have done Leyda proudly. The noble volume, as befits a first social and aesthetic history of the Russian (and Soviet) film, is in fine grey and amply illustrated. J. HORNE

LETTERS TO THE EDITOR

Television in the Science Classroom

Sir:

On the whole Mr Pitt's impressions of school television in this country seem quite fair but I am afraid he has been guilty of a few slight errors of fact! In particular, it is quite untrue to say that neither the BBC nor the television companies would attempt a history of science. In fact, Associated-Rediffusion did just this in the last school year 1959–60. A series of twenty-four programmes, under the title "Endless Adventure", traced scientific development from prehistoric times to the latest developments such as radio-astronomy and atomic energy. You will remember that Prof. Tolansky reviewed some of these "Endless Adventure" programmes very favourably in your own journal. ENID LOVE

Head of Schools Broadcasting, Associated-Rediffusion Ltd.

Scientific Freedom in the Soviet Union

Sir:

I am sorry you have allowed your interesting publication to be drawn into the untruths of "cold war" politics. I don't know R.K.M., but he is obviously not conversant with Marxist dialectic or he would not try to interpret Soviet scientists' approach to truth into terms of what we would consider to be personal and libellous statements. But perhaps Mr R.K.M. is not very concerned with philosophy or truth or he would realise that his last sentence is self-contradictory. In any case one swallow does not make a summer (or one hailstone a winter). J. WALTON

SCIENCE ON THE SCREEN

Two receptions were recently arranged by the British Association for the Advancement of Science—one was on films and other visual material on Physics, and the other on technical education. These programmes revealed a basic problem for science and technical teachers. Do they get the films they need when they need them, and do they use the films available? In spite of our rapid advance into the Space and Electronic Age, it seems doubtful that teachers are really using films as extensively as they might. It is also doubtful whether films available are designed to fill gaps in the curriculum.

It is obviously impossible for school laboratories to reproduce complex and expensive experiments. Even the teachers themselves are often out of touch with modern scientific trends. Industrial research and academic research are often almost isolated from each other and from the rank and file of science teachers. The films I have seen recently are often clear and concise but are not aimed at a precise target.

As usual budget is at the bottom of all the trouble. A few firms collaborated wholeheartedly with such organisations as the Educational Foundation for Visual Aids. Others, if they produce films at all, are mainly concerned with the Public Relations task of creating a vaguely sympathetic climate towards the work of their industry.

Principles of X-rays

Sound. Black and White. Running time 17 minutes. Great Britain 1960. Produced by Mullards Ltd, with the National Committee for Visual Aids in Education. (*Available on hire from the Foundation Film Library, Brooklands House, Weybridge, Surrey.*)

This is the latest addition to the EFVA's Advanced Science series. Using animated diagrams and actual shots it explains the nature, generation, and some modern applications of x-rays in terms of atomic physics.

It uses a direct factual approach to modern medical, scientific, and industrial uses although the tempo is inclined to be a little fast. The animated diagram is good and clear, except that some of the atomic diagrams do not contrast sufficiently with the darkish grey background; the first atomic diagram looks rather too much like a target after a not very successful shoot on the miniature range. This demonstrates how important it is that scientific diagrams should be very carefully planned and designed so that possible mis-interpretation and distraction is eliminated.

The actuality shots are photographically rather dark and unclear. Obviously the cameraman has found the situations in which x-rays are used difficult to light and photograph. In a teaching film, it is essential that detail shall be communicated clearly by unambiguous images. This is a case in which more careful choice of shot and better lighting could greatly have increased the teaching value.

However factual a commentary may be, it is a pity if the voice of a commentator becomes dry and uninteresting. Although its contents are of great interest, the commentary is read in a monotone, the commentator should listen to the inspiring way in which good science teachers put over their subject. As with all the EFVA films, however, the educational content is impeccable.

Introduction to Optics

Sound. Colour. Running time 23 minutes. U.S.A. 1960. Produced by the U.S. Physical Science Study Committee. (*Not at present available in Great Britain.*)

This is one of a new series of Physics Teaching films designed for Secondary School use in America. It is a demonstration lecture by Dr E. P. Little. It deals with the effects of diffraction, scattering, refraction and reflection on the distribution of light rays.

At the beginning some rather mediocre camera work and the blueness of the print made me think that this was just another film. It turned out to be an absolutely brilliant *tour de force*; I have seldom seen a better educational film. Dr Little, with a gently unobtrusive, but entirely relevant, sense of humour would stimulate even the dullest pupil. He begins by stressing that this film is not going to explain light, but show its effect. He started to do a complex experiment and then said in a delightfully relaxed way, "I'm not going to do this experiment, you couldn't see much anyway". He then broke off the experiment and went on to another. This caused some controversy amongst the teachers in the discussion after the film, but there is little doubt that it would make boys ask to see the experiment and would stimulate the teacher to continue where the film leaves off. Films should be designed to be an integral part of class teaching.

Every experiment was shown dramatically. For example, he passed a light through a smoke-filled box and then demonstrated that a magnetic field and an electric current caused no deflection of the light rays. By implication he emphasised that the scientist must try every possible method whether he considers any positive results probable or not.

The demonstration of refraction by showing a girl with her feet in water and then letting a frogman photograph her feet was most effective. The way that they could be separated from her body in the photograph was both amusing and memorable. The film ended with a final experiment which Dr Little did not explain. He said that this is a single clue on which the students could base their future study of ray optics.

This film should be studied by all film makers and teachers, who could learn much from its techniques. The complete and intelligent marriage of commentary and visual is outstanding. The simplicity of the script makes a somewhat complex subject comprehensible. Its only fault is the bad quality of some of the photography, but this is soon forgotten because of the sympathetic presentation.

Motion and Time

Sound. Colour. Running time 14 minutes. Czechoslovakia, 1958. Produced by Vosahlik for the Czechoslovak Popular Science Film Studies. (*Available on free loan from the Czechoslovak Embassy, 7 Kensington Palace Gardens, W.8.*)

This is an interesting attempt to explain Einstein's Theory of Relativity to the masses. The opening sequence shows two clocks which flash and bleep once per second. At first they are completely synchronised. As one clock accelerates up to the speed of light, it goes slower. By trick photography it is shown how objects become shorter as they accelerate.

A little local train flies up into space, and the effects of relativity are demonstrated. From this moment on the film is no longer clear. As so often happens, an amusing and imaginative treatment of a complex subject is inclined to confuse and distract. It is by no means certain that the uninformed, seeing this film, would either understand or believe the

theory of relativity. Nevertheless this is an intriguing little film that is well worth seeing.

The Invisible Force

Sound. Colour. Running time 24 minutes. Great Britain, 1960. Produced by Mullards Ltd. (*Available on free loan from Mullard House, Torrington Place, London, W.C.1.*)

This film claims to be a popular account of magnetism, including demonstrations of the way in which its existence was discovered and how fundamental research has revealed more of its nature. The film makes reference to such new magnetic materials as magnadur, ticonal, and ferroxcube. This film starts well, explaining magnetism, but as it goes on it becomes obvious that the film makers were fundamentally Public Relationists rather than scientists. The commentary and the film only come to life when they are dealing with a proprietary product. This is to be deprecated. The whole treatment would have gained in impact and stature, if it had been more objective and less a vehicle for only very slightly camouflaged advertising.

Discharge through Gases

Sound. Black and White. Running time 11 minutes. Great Britain, 1958. Produced by The Educational Foundation for Visual Aids with Mullard Ltd. (*Available on hire from the Foundation Film Library, Brooklands House, Weybridge, Surrey.*)

A clear and relatively simple film on discharge lighting. Discharge lighting, Thyratron valves, and electronic counting-tubes are dependent upon the different phenomena caused when electric currents pass through gases. Varying effects can be achieved by changing the gas and the gas pressure. Simple experiments are shown to demonstrate these effects and explain their meaning.

The diagrams are good and clear except that cloudy and irregular backgrounds used to get the effect of space are actually confusing. It cannot be pointed out too often that artistic licence hinders scientific explanation.

An Introduction to Jet Engines

Sound. Colour. Running time 14 minutes. Canada, 1959. Produced by the National Film Board of Canada. (*Available on hire from the Central Film Library, Bromyard Avenue, Acton.*)

A Royal Canadian Air Force Training Film on the Principles of Jet Propulsion. Service instructional films are usually good, because they need to be good. If young men are to fly immensely fast ram-jets, they must understand the mechanism which carries them into the supersonic range. Starting with a rocket, the film develops by a simple series of acceptable analogies to the jet engine. The film is largely animated diagrams but the choice of colours is not as good as it might be. For example, the compressor impeller is shown in red when, of course, it is metallic. This gives the impression of flame and great heat which can be confused with the flame in the actual combustion chamber. In spite of this, however, it is a very good, clear, yet simple film.

An Introduction to Modern Gears

Sound. Black and White. Running time 31 minutes. Great Britain, 1958. Produced by Shell Mex and BP Ltd. (*Available on free loan from Shell Mex and BP Ltd, Shell Mex House, Strand, London, W.C.2.*)

This film was planned as a training aid for schools, technical institutes and Company Training Schemes and intended for technical students from their middle teens to early twenties. It is a film lecture summarising the main function of gears and deals with the principles of gear design and the techniques of gear cutting and generation.

The visual part of the film is generally clear but the vocabulary used presupposes that the students already have a considerable knowledge of the subjects. It would be useless for boys to see this film if they did not already know the meaning of such words as "helical", "involute", "mesh", "pitch", "epicyclic", and so on. When films are aimed at the training of technical students it cannot be assumed that they have a complete job vocabulary. The value of this sort of film may be to teach them words as well as techniques.

THE PROGRESS OF SCIENCE

(*continued from page 47*)

Schrödinger was then a professor at the University of Zürich. He was thirty-eight years old—an age at which most scientists, particularly theoretical physicists, have shown the nature of the contributions they are capable of making to knowledge. Nobody now reading the twenty-eight or so papers published by Schrödinger before 1926 would be able to see any portents of the greatness of the work which was to come, but within a few months a series of papers appeared which started from the analogy between mechanics and optics (brought out particularly in the work of Hamilton) and led naturally (using ideas similar to those of de Broglie) to a wave equation which not only contained in it all the known results of the Bohr quantum rules but also gave unique answers for all the open problems for which these rules were not applicable.

In these papers, Schrödinger not only set up the basic equations and illustrated their use but also showed how to deal with all the important soluble problems, how to take account of the effect of perturbing electric and magnetic fields, and how to deal with time-dependent problems such as the effect of electro-magnetic radiation on atoms. One of the papers demonstrates the equivalence of wave mechanics with the Heisenberg matrix mechanics and shows how to calculate the matrix elements appearing in that theory from the Schrödinger wave functions. The papers also show a clear understanding of the fact that the extension to relativistic velocities required still a new idea which was supplied later by Dirac in his relativistic wave equation for the electron.

This series of papers makes wonderful reading even today. The power of reasoning by which all the immediate consequences of the new approach are argued out is matched by an elegance and clarity of exposition which has yet to be surpassed by the best textbook of quantum mechanics. It is not surprising that before the last of these papers was published, other authors were following Schrödinger's lead and were investigating the new wave equations in further detail.

The one major concept of non-relativistic quantum theory which was still to come was the physical interpretation of the wave functions and their relation to the probability of observations. Schrödinger himself was hoping to be able to attribute to this wave function a physical reality by which the particle aspects of mechanics would be only classical concepts applicable on a sufficiently large scale. He was somewhat reluctantly converted to the statistical interpretation when the further study of his equations—particularly of their application to many-body problems—made this inevitable.

In recognition for his work on wave mechanics, Schrödinger shared the Nobel Prize for physics in 1933 with Dirac. This award and the many other honours he received, which included the foreign membership of the Royal Society, were hardly necessary to demonstrate how important a part his work had played in physics. His most effective memorial will

be the appearance of the Schrödinger equation in every textbook on fundamental physics or chemistry.

After 1926, he maintained wide interests. Apart from quantum theory, he continued work on general relativity and statistical mechanics, both of which had been early interests in his scientific work. He was also attracted by biological problems and wrote the very readable book, "What is Life?" His writings include also books and articles on the connexion between science and the humanities, and all these show the same mastery of language and of expression as his writings in physics.

As a physicist, he liked to work by himself. Hardly any of his work was done in collaboration, and he had few pupils, so that his profound influence from physics came almost entirely through his published papers.

He moved from Zürich to Berlin in 1927, and in 1933, when life under the Nazi regime became intolerable, he came to Oxford. In 1938 he returned to Austria to accept an invitation from the University of Graz, but after the German occupation of Austria, he left with some difficulty. After some wandering, Schrödinger finally settled in Dublin, where he was the senior professor at the Institute for Advanced Study until his return to Vienna in 1956. R. E. PEIERLS

RNA AND MUSCULAR CONTRACTION

The newly formed British Biophysical Society held its first meeting at King's College, London on December 19–20 with symposia on "Comparative Studies of Muscular Contraction" and "The Structure and Function of Ribonucleic Acid (RNA)" and two sessions of contributed papers on a variety of subjects. The Society was formed after the Faraday Society carefully considered the future of its Colloid and Biophysics Committee and recommended the organisation of a new and independent biophysics group. Until an election later this year, the Society is being guided by a steering committee under the chairmanship of Prof. J. A. V. Butler, F.R.S.

At the symposium on muscular contraction, evidence was presented showing that the basic structure in the α-class of muscle proteins involved the association together in the form of a coiled-coil of two polypeptide chains both in the α-helical configuration, a structure originally produced by Crick & Pauling and Corey. The intensities of the equatorial x-ray diffraction spots from striated muscle—from which information about the large-scale organisation of the protein chains within the muscle may be deduced—were shown to be a function of the muscle length rather than muscle treatment, as was thought previously; this is consistent with the sliding filament model of muscular contraction. On the physiological level it was questioned whether it was legitimate to break down the properties of muscle into hypothetical units, for example, the series-elastic component and the non-elastic contractile component. Conflicting views were advanced about whether the properties of muscle can be described without recourse to a particular "catch" or "ratchet" mechanism.

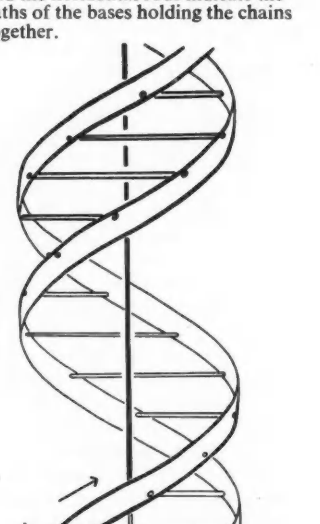
The structure of RNA is currently being examined both by studies on RNA itself and on synthetic polynucleotides made from nucleotide bases A, U, G, and C (adenine, uracil, guanine, and cytosine) which make up RNA. At the symposium on RNA, studies on poly-A and a 1 : 1 complex of poly-C and polyinosinic acid (inosine is very similar to guanine) were reported. Some fibres of the complex give an RNA-like x-ray pattern while others give a DNA-like pattern. A comparison of the x-ray pattern from extracted RNA and the patterns from the RNA in whole ribosomes from three sources has established the relevance of the former to the structure of the RNA within the ribonucleoprotein particles (ribosomes) of the cellular cytoplasm.

The role of *messenger* RNA in carrying genetic information from the DNA in the cell to the site of protein synthesis (the ribosomes) and the role of *transfer* RNA as an adaptor molecule for the synthesis of a particular amino-acid were described. It was shown that the base ratios in transfer RNA (that is, A : U and G : C) were both 1 : 1 for the RNA from three different sources. The corresponding ratios in DNA (where thymine T replaces U) are A : T and G : C, which are both 1 : 1. In DNA, A and G and C associate together between the two strands of the double helix as proposed in the Watson-Crick base-pairing scheme; this scheme was shown to be consistent with the latest x-ray and model-building data.

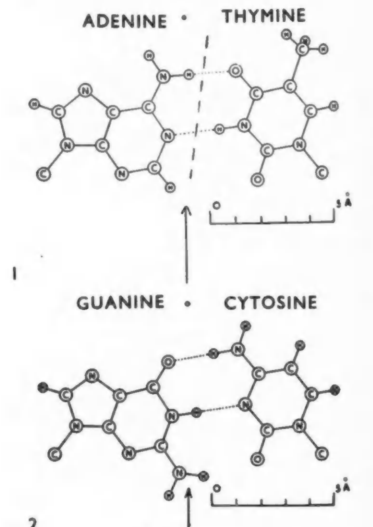
The major structural inference from the work presented was that RNA is probably in a double-helical configuration rather like DNA but with not such a well-ordered structure. The possible complexities of the coiling of the RNA chain were discussed in relation to the roughly spherical RNA core of turnip yellow virus.

One group of the contributed papers was devoted to an examination of the structure and properties of cilia and flagella. Electron microscope and other evidence was presented relating to the structure, nature, and function of the basal bodies from which the cilia originate and to the structure of the cilia from a number of sources, both plant and animal. Some x-ray and biochemical data was presented on the properties of the cilia isolated from the organism. The flagella-fibrous appendages arising from the periphery of bacteria

The Watson-Crick structure of DNA. The two ribbons symbolise the two phosphate-sugar chains and the horizontal rods indicate the paths of the bases holding the chains together.



Pairing of bases in the DNA structure: (1) Pairing of adenine and thymine, and (2) pairing of guanine and cytosine.



have been examined by x-ray methods for a number of years. The interpretation of the x-ray pattern in terms of the packing arrangement of the polypeptide chains within a single flagellum was presented.

INTERNATIONAL SYMPOSIUM ON THE MOON

A symposium devoted solely to a discussion of the Moon brought 100 scientists from six countries together at the Pulkovo Observatory near Leningrad last December under the sponsorship of the International Astronomical Union.

The main event of the meeting—at least for the non-Soviet participants—was the first opportunity to get acquainted with the full details of the far side of the Moon that were obtained with the lunar probe *Lunik III*. The U.S.S.R. Academy of Sciences has now published a full album of thirty photographs with the results of detailed studies performed independently at Pulkovo, Moscow, and Kharkow observatories. Exercising their right to assign names to many of the newly discovered formations, they have chosen a select international society for the far side of the Moon. Side by side with the great Russian names of Lobachevski, Lomonosov, Mendeleyev, Popov, and Tsiolkovski are the equally distinguished French names of Pasteur, Madame Sklodowske-Curie, and Joliot-Curie, with Jules Verne looking on from some distance with great dissatisfaction. The great British scientist James Clerk Maxwell rubs uneasy shoulders with the fiery Giordano Bruno. To maintain complete impartiality, the Russians have included one American—Thomas Alva Edison—and one Chinese—Tchui Chin.

Another highlight of the conference was a report of the gas outburst observed from the crater Alphonsus in November, 1948 by Dr Kozyrev and a detailed spectrophotometric analysis of it by Dr Kalinyak. While the discharge of about 1,000,000 cubic metres of carbon gas at that time appears to be established beyond any doubt, some differences of opinion still exist about the source of excitation of the observed Swan bands of the C_2 spectrum. Although Kozyrev believes the excitation to have been thermal, Kalinyak proved that the ultra-violet radiation from the setting Sun would have been sufficient for the purpose.

The greatest riddle of all—the underground origin of the C_2 molecules—remains as yet unresolved, however, and with it the possibility of finding sizeable reservoirs of hydrocarbons (oil?) beneath the Moon's crust. Also unresolved, is the question of juvenile water on the moon although Dr Gold of the U.S.A. argued of its possible presence in frozen form beneath the surface details usually referred to as "domes".

All these questions are intimately connected with the problem of the origin and evolution of the Moon as a whole. The symposium reflected a remarkable inclination towards the view—due largely to Prof. H. C. Urey—that the Moon originated as a cold body by an agglomeration of solid particles, independently of the Earth, and that the internal heat the Moon may now have has been produced since then by radioactive processes—mainly by the spontaneous disintegration of potassium-40. However, a more accurate schematic model of the lunar globe as well as the overall rate of degassing and desiccation remain uncertain within wide limits. The same is true of the relative importance of the different processes which may have cooperated in the shaping of the lunar surface as we see it today—the external (impacts) and internal (degassing).

POWER TRANSMISSION AT 400,000 VOLTS

With the demand for electric power doubling every ten years, there is always a need to transmit larger and larger amounts of power. Since power stations are tending to get bigger and, in the case of nuclear stations, situated in isolated areas, it is also becoming necessary to transmit this increasing supply of power in larger blocks.

In Britain, a 132,000 volt national grid system has been in service since 1930. A start was made in 1951 on a super-grid operating at 275,000 volts that would straddle the earlier system and link whole areas together, but with the system not yet fully complete, the rise in demand has been so high further steps have had to be taken to increase its capacity.

The problem of transmission can be met in three ways—by increasing the size of the wire or number of wires in existing lines, by building more lines, or by raising the voltage. The first method is not feasible because it is not practicable to equip existing steel towers with more conductors or conductors which are significantly larger than those now in use and it would not be economical to redesign the towers. The building of more overhead lines—the second method—is increasingly difficult in a country such as Britain where amenities are highly prized and where, in many cases, the approaches to most cities are so built up that sites for large pylons cannot be found.

The third method appears to be the only practical solution but it is not an easy one. Two problems face the engineers concerned with high voltage transmission: first, corona discharge and its associated problem of radio-television interference; second, the problem of flashovers.

At voltages above about 50,000 volts, all conducting metal begins to acquire a faint blue glow that is accompanied by a sizzling noise. The effect increases rapidly as the voltage is raised. At about 100,000 volts, any sharp point or edge will produce a high charge density and begin to emit a blue flame several inches long. The accompanying electromagnetic noise may interfere with television reception within a radius of half a mile. To avoid this discharge, the utmost care must be taken in the design of every detail of the insulators, the supporting clamps which hold up the wire, and all the other parts; nuts and bolts present a very difficult problem.

The flashing over of glass and porcelain insulators is the other hurdle for the engineers who have to contend with one of the worst atmospheres in the world. Corrosive smokes from chemical factories, fumes from power stations, and general industrial dirt foul insulating surfaces; the problem is further aggravated within a dozen or so miles of the coast by airborne salt—a good conductor of electricity.

The Central Electricity Generating Board's decision to step the grid voltage up to 400,000 volts is a courageous one. The U.S.S.R. is the only other place that a voltage this high is used although Sweden has had a 380,000 volt line in service for about eight years. (The Soviet

Union has gone up to 600,000 volts on an experimental line and the U.S. has pushed a 4·3 mile prototype up to 750,000 volts.)

Much research has taken place into the design of all the components, of course, and insulators with a longer insulating path have been evolved. Exhaustive tests with the simulation of pollution, ice, snow, and driving rain have been carried on for some years but this step is, nevertheless, a venture into the unknown as no tests can exactly duplicate the slow seasonal changes in humidity, the sudden gusts of salt-laden air, or the stray wisps of smoke-borne chemicals from some new process.

The first of the 400,000 volt lines will be commissioned this year. Each line of the 136-ft.-high pylons will carry 2 million kilowatts over its twin circuits.

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LIFE'S A QUEST

Nature's been bountiful. There's plenty of coal for factory furnaces, plenty of oil for cars and ships, plenty of water to grow crops and generate power: plenty for everyone, but not just for the asking. Much of this bounty can only be found by quest and won by force—the force of explosives scientifically designed for the job. In unlocking metal ores from the earth, one charge of I.C.I. explosive does the work of scores of men. In Middle Eastern deserts, I.C.I. seismic explosives speed the search for oil. Specially safe I.C.I. explosives ease the task of British coal-miners, and I.C.I. has provided the blasting power for the great new hydro-electric schemes in the North of Scotland. Wherever there are mountains to be moved or mineral riches to be won, I.C.I. explosives are there—the power behind man's power to wrest plenty from Nature.

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